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PROCEEDINGS  
OF THE  
AMERICAN SOCIETY  
FOR  
HORTICULTURAL SCIENCE  
FOR  
1938

*Thirty-fifth Annual Meeting*  
*Richmond, Virginia*  
*December 28, 29, and 30, 1938*

VOLUME 36

Published by the Society  
Edited by the Secretary, H. B. Tukey  
Geneva, New York  
April, 1939



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# OFFICERS AND COMMITTEES FOR 1939

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E. C. AUCHTER

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E. F. PALMER (1939)	E. V. HARDENBURG (1942)
W. A. RUTH (1940)	PHILIP BRIERLEY (1943)

# CONSTITUTION

## ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

## ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

## ARTICLE III

*Voting members:* Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

*Associate members:* Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

## ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

## ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society, who, together with the chairmen of the standing committees, shall constitute a Council to act upon all applications for membership. These officers shall be elected annually by ballot.

## ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

# BY-LAWS

SECTION 1. The President and other officers shall perform the usual duties of their respective offices. The President shall also deliver an address at each regular meeting.

SEC. 2. There shall be a Committee on Nominations consisting of two members from each of the sectional groups who shall be nominated by the Executive Committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), and representatives, and for the sectional chairmen, who shall be chosen in consultation with the sections.

SEC. 3. There shall be an Executive Committee consisting of the retiring president, who shall be chairman, the vice-president, the sectional chairmen, two members elected at large for terms of two years each, retiring in alternate years, and the president and secretary-treasurer. This committee shall perform the usual duties devolving upon such committees and shall present at each annual meeting nominees for members of the nominating committee.

SEC. 4. The Committee on Nominations shall nominate referees and alternates upon special subjects of investigation or instruction, which may be referred to its consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned them and to report the present status of the same.

SEC. 5. There shall be a Committee on Program, consisting of four (4) members, of which the secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society.

- SEC. 6. The annual dues of the Society shall be four dollars.  
SEC. 7. Ten members of the Society shall constitute a quorum.  
SEC. 8. There shall be an editorial committee consisting of five members. One member shall be elected each year to serve for five years.  
SEC. 9. There shall be a committee on sectional groups and membership.  
SEC. 10. There shall be a committee on local arrangements.

## SOCIETY AFFAIRS

### RESUMÉ OF THE ANNUAL MEETING AT RICHMOND, VIRGINIA, DECEMBER 28, 29, and 30, 1938

The thirty-fifth annual meeting of the Society was held at the Jefferson Hotel and in the Educational Building of the Second Baptist Church. There were 247 papers presented in 20 sections, including a joint session with the American Society of Plant Physiologists and the Physiological Section of the Botanical Society of America; the Potato Association of America; Section "O" of the American Association for the Advancement of Science; and the American Phytopathological Society. Round table discussions included a round table on fruit varieties; a round table for extension workers; a round table on vegetable varieties; a round table on educational methods; and a round table on raspberry breeding. The dinner and social evening, in charge of the Virginia workers in horticulture with Professor A. H. Teske as toastmaster, was held at the Commonwealth Club. Local arrangements were in charge of Professor Teske assisted by H. W. Ridgway and J. F. Watson. The "all Virginia" menu and the fine social aspects of the meeting were enhanced by Dr. Liberty Hyde Bailey, first president of the Society, by the Hampton Quartet, and by motion pictures of Historical Virginia.

### RESUMÉ OF THE MEETING OF THE SOUTHERN SECTION

The third annual meeting of the Southern Section was held in conjunction with the convention of the Association of Southern Agricultural Workers in New Orleans on February 1, 2, and 3, 1939. The program carried 47 papers which were given in seven sessions. Two sessions were held for symposia, two for joint sessions, and three for the presentation of papers of general interest. The symposia were: "Research with Sweet Potatoes", with Professor R. A. McGinty as Chairman, and the "Application of Statistical Methods to Horticultural Research", with Dr. S. H. Yarnell as Chairman. The joint sessions included one with the Marketing Section on "Sweet Potato Marketing Methods" with Professor H. S. Moles as Chairman, and one other with the Agronomy Section of the Association of Southern Agricultural Workers on "The Influence of Soil Fertility and Fertilizers on Yield and Quality", with Dr. J. B. Edmond as Chairman.

The annual breakfast was held at the St. Charles Hotel with Mr. G. L. Tiebout giving an address on "What Southern Horticulture Needs". Local arrangements were in charge of Dr. J. C. Miller.

The following officers were elected for 1939-40: Chairman, Professor R. Schmidt; Vice-Chairman, Dr. L. H. Cochran; Secretary, Dr. J. B. Edmond. Members of the Executive Committee are Dr. J. C. Miller (1940), Dr. B. L. Wade (1941), and Dr. H. H. Zimmerley (1942).

### REPORT OF THE SECRETARY-TREASURER

On December 20, 1938, when the books of the Society were closed for the year, there was on hand a balance of \$5,124.00, or an increase of \$253.20 over the preceding year. Membership increased to 715 from 665, a gain of 50 members as compared with a gain of exactly 50 members during the year immediately preceding. The sale of PROCEEDINGS to libraries was about the same as last year, \$1,477.90. Because of the added burden of bookkeeping, mailing, and clerical effort coincident with the handling of reprints, etchings and halftones, and extra pages, the charges for clerical assistance were higher than in the previous year, but the profit made from handling these items more than offset the charges for clerical help.

## TREASURER'S REPORT

### *Receipts*

Dues (1938).....	\$3,116.00	
Proceedings sold (includes bound volumes).....	1,477.90	
Extra pages purchased by authors.....	517.60	
Reprints and etchings sold.....	1,688.47	
		<hr/>
	\$6,799.97	
Interest on money in savings account.....	79.27	
Balance on hand December 15, 1937.....	4,870.80	
Bills receivable, outstanding accounts.....	105.30	
		<hr/>
		\$11,855.34

### *Expenditures*

Expenses of Indianapolis meeting.....	\$ 79.40	
Printing Proceedings, Vol. 35.....	4,193.72	
Printing programs, letterheads, billheads, membership slips and envelopes.....	171.00	
Printing reprints.....	701.34	
Halftones and etchings for Proceedings.....	514.30	
Secretary's office, includes clerical assistance.....	502.50	
Postage and express, general office use and shipping Proceedings.....	300.43	
Stamped envelopes.....	102.94	
J. H. Long, withdrawal of membership.....	4.00	
Proceedings purchased for resale.....	50.00	
Maps of Richmond, Virginia—sent to membership.....	4.02	
Exchange on foreign checks during 1938.....	2.39	
		<hr/>
Total expenditures.....	\$6,626.04	
On hand December 20, 1938.....	5,124.00	
Bills receivable.....	105.30	
		<hr/>
		\$11,855.34

December 28, 1938

Audited, found correct, and approved. We find these books to have been exceptionally well kept

M. B. DAVIS,  
G. F. POTTER,  
*Committee*

## REPORT OF THE EXECUTIVE COMMITTEE AS ADOPTED BY THE SOCIETY

1. The Executive Committee recommends that members of the Society be reminded of the high cost of publishing tables in the PROCEEDINGS and that they be asked to give special consideration to the methods of preparing data which will reduce the cost of tables whenever possible yet without injury to the paper.

2. The Executive Committee approved the expenditures made by the Society during the year

3. The Executive Committee recommends that the incoming President appoint a committee of five to revise the Constitution and By-Laws of the Society, specifically to define the duties of officers and committees, and to study the formation of sectional groups, membership, junior membership, and other matters pertaining to the welfare of the Society.

4. The Executive Committee recommends that titles of papers which are to be presented at sectional meetings of the Society, and which are also to be submitted to the society for publication in the PROCEEDINGS, must be submitted to the program chairmen of the respective sectional groups on or before the closing date for the receipt of titles for the annual meeting by the program chairman of the

Society, the program chairmen of the sectional groups in turn to submit these titles to the program committee of the American Society for Horticultural Science within 10 days of the closing date for receipt of titles. Such papers shall go through the usual editorial channels of the Society, including submission of the paper to the secretary of the Society on or before the time of the annual meeting, as now required for all papers to be published in the PROCEEDINGS.

5. The Executive Committee recommends that the matter of junior membership be referred to the committee to consider the revision of the Constitution and By-Laws.

6. The Executive Committee recommends that the Society approve the formation of a Western Section of the American Society for Horticultural Science.

7. The Executive Committee appointed the following as members of the Nominating Committee: V. R. GARDNER, *Chairman*; W. P. TUFTS, J. C. MILLER, S. L. EMSWELLER, J. W. LLOYD, and L. C. CHADWICK.

## REPORT OF THE NOMINATING COMMITTEE

In its report the Nominating Committee submitted the names of officers and committees as shown on page x of these PROCEEDINGS, with the exception of the Nominating Committee, which was nominated by the Executive Committee in accordance with the Constitution. The secretary was instructed to cast the vote of the Society for the officers and committees as nominated, and their election was declared.

## REPORT OF THE COMMITTEE ON EDUCATION

Dr. J. H. Gourley, as chairman of the committee on education, reported that the committee recommended that the first course in horticulture in the colleges and universities be studied, and that a session be held at the Columbus meeting of the Society in 1939 to discuss various angles of the problem. The report was adopted and it was voted further to continue the committee on education.

The committee to study the teaching of horticulture in this country, as appointed by the president, is as follows: Dr. R. A. Van Meter, Massachusetts State College, *Chairman*; Dr. Kenneth Post, Cornell University, Dr. Roy Marshall, Michigan State College, and Dr. G. J. Stout, Pennsylvania State College.

## REPORT OF ROUND TABLE ON RASPBERRY BREEDING

The following Stations presented outlines of their raspberry breeding work: Oregon, New York, Illinois, Tennessee, North Carolina, and Beltsville, Maryland (United States Department of Agriculture). Dr. G. M. Darrow outlined his experience with sterility in various *Rubus* crosses. Professor J. Harold Clark, of New Jersey, and others discussed the technique and usefulness of chemical treatments for changing chromosomes in plants. Later in this meeting Dr. Haig Dermen exhibited strawberry plants of various chromosome counts. Sprouting seed soaked 5 hours in a .2 per cent colchicine solution gave best results in Dr. Dermen's work. Professor C. F. Williams, Dr. Close, and others discussed parentage including species available and pure line vs heterozygous-pedigreed parents. It was agreed that pure lines were more likely to be developed where a given variety was easily grown.

North Carolina has been making many crosses with *Rubus biflorus*, Tennessee with *R. kuntzeanus*, Beltsville Station with *R. parvifolius*. The Geneva, New York, Station is working on developing klendusic varieties. Minnesota and Oregon are developing pure lines. Illinois is using *R. coreanus* and parents secured from the North Dakota Station. It was generally agreed that we lack an evaluation of *Rubus* species for breeding purposes.

## REPORT OF RESOLUTIONS COMMITTEE

*Whereas*, several individuals and organizations have contributed to the success of the Richmond meetings of the American Society for Horticultural Science,

*Be it resolved* that this Society request its secretary to convey to the following

persons and organizations its sincere appreciation and thanks for their expressions of genuine southern hospitality:

To PROFESSORS A. H. TESKE, J. F. WATSON and H. W. RIDGWAY of the local arrangements committee for their excellent work in providing the many things which have made our stay here so enjoyable and profitable.

To PROFESSOR W. B. MACK and the other members of the program committee for their painstaking work in arranging the details of the program.

To the management of the Jefferson Hotel, the officers of the Second Baptist Church, the Boy Scouts, the Virginia State Chamber of Commerce, the Richmond Chamber of Commerce, and the Commonwealth Club for their wholehearted cooperation in rendering personal services and making available the facilities for the meetings.

*And be it further resolved* that we express our appreciation of the fine work rendered by the officers and committeemen of our Society during the past year, especially to our secretary, DR. H. B. TUKEY.

WM. F. PICKETT, *Chairman*

ERNEST ANGELO

ORA SMITH





# Seasonal Variation of Oxygen and Carbon Dioxide in Three Different Orchard Soils During 1938 and its Possible Significance

By DAMON BOYNTON and WALTER REUTHIER, *Cornell University,  
Ithaca, N. Y.*

THIS report is concerned with the variations of oxygen and carbon dioxide percentage in the atmosphere of a sandy loam orchard subsoil, a light silty clay loam orchard subsoil and a silty clay orchard subsoil for the period from November 14, 1937 until October 11, 1938.<sup>1</sup>

The sandy-loam soil is rather uniform in texture and structure to a depth below 6 feet. Topography at the locations sampled is rolling. The field capacity of the subsoil layers is about 22 per cent of volume and the total porosity is about 38 per cent so that the non-capillary porosity amounts to about 16 per cent. Considerable numbers of apple tree roots are found at a depth of 6 feet and below. Apple trees situated on similar soils are high in productivity (6).

The light silty clay loam soil is also rather uniform in texture and structure to a depth below 6 feet. Topography at the locations sampled is gently rolling. The field capacity of the subsoil layers varies between about 36 and 38 per cent of volume and the total pore space varies between 41 and 45 per cent so that the non-capillary porosity seems to be between about 6 and 8 per cent (4). Usually considerable numbers of apple tree roots extend below 5 feet. Apple trees situated on this soil are above average in productivity (6).

The silty clay soil is heavier in texture in the upper 3 feet of the profile and is more compact at a depth of 4 feet and below than the light silty clay loam soil. Topography at the locations sampled is gently rolling. The non-capillary porosity is less than in the light silty clay loam in some of the layers above 4 feet and seems to decrease to about 1 per cent of the total volume at the 4 foot depth (3, 4). There is little mottling in the profile, but there is a marked accumulation of carbonates between the 3 and 4 foot depths. Few apple tree roots are found below a depth of 4 feet (2, 6). Apple trees on this soil are relatively short-lived, and are close to the margin of economic productivity (6).

The weather during the growing season of 1938 at the sampling plots was dry until the middle of September. Although there were no protracted periods without rainfall, only 11 inches of rain fell at the Cornell University orchards between April 1 and August 31, 1938. This was more than 5 inches below normal for the period, almost 11 inches less than had fallen during that time in 1937, and more than an inch

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<sup>1</sup>There are important orchard soils on which the extent, depth, and activity of the root systems may limit the productivity of fruit trees even though the usual soil indices do not give clear evidence of water-logging, poor drainage, or poor aeration. Knowledge of the variations of oxygen and carbon dioxide percentage in the atmospheres of these soils and the conditions of weather, tree activity, and soil profile, structure, texture, and moisture associated with these variations are necessary steps in their evaluation.

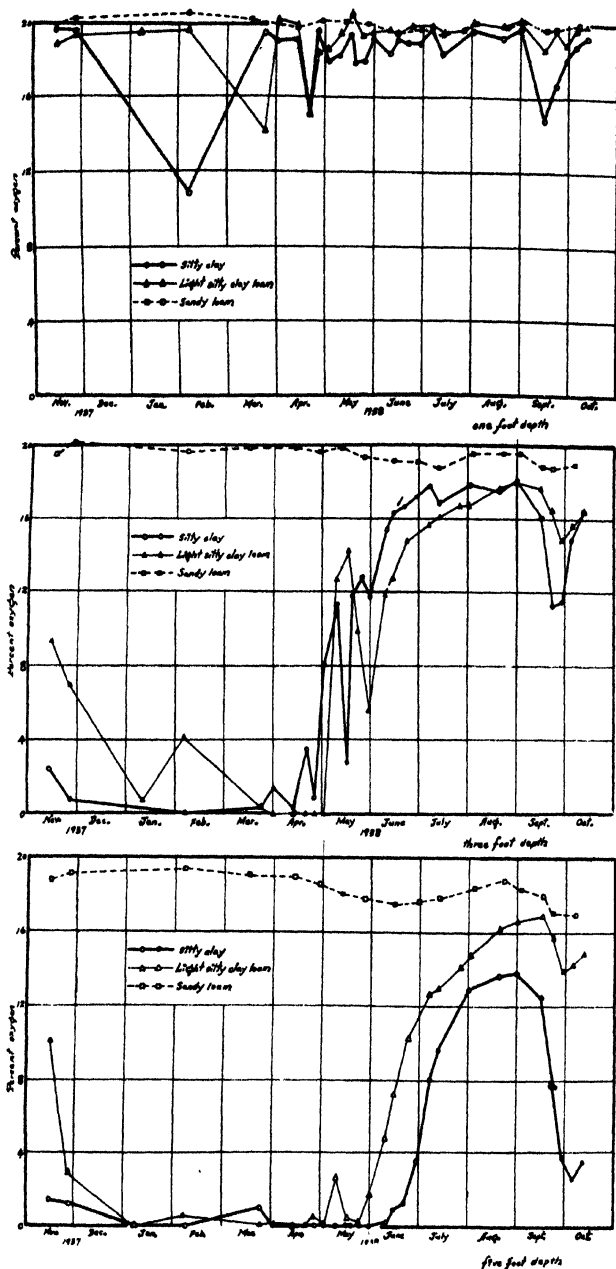
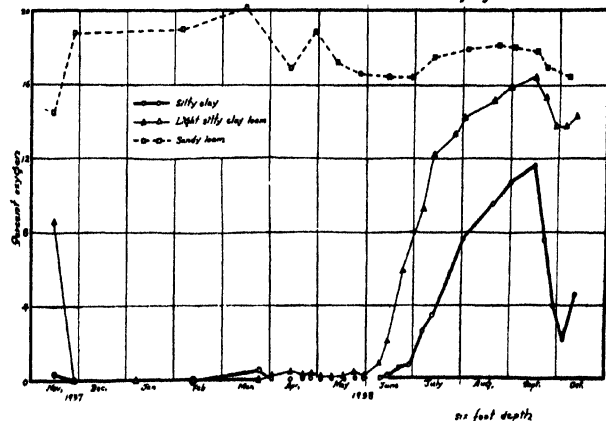
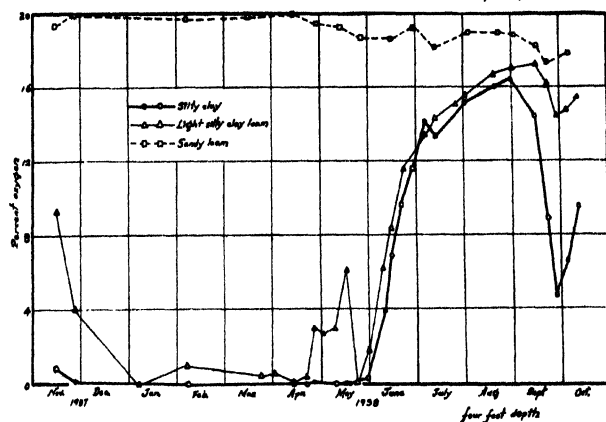
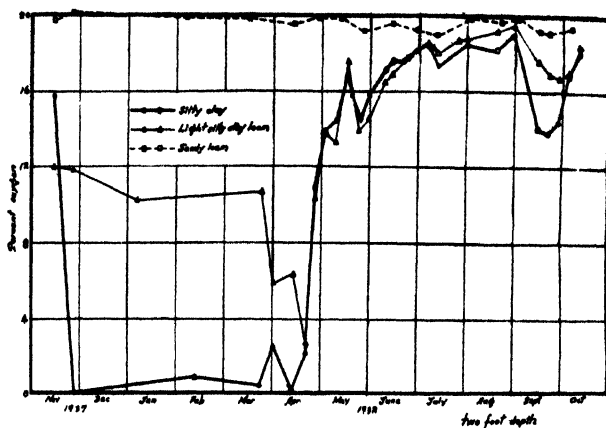


FIG. 1. Seasonal changes of oxygen



percentage in three orchard subsoils.

less than fell during that time in the "drought" year of 1936. From the 8th to the 23rd of September,  $6\frac{1}{2}$  inches of rain fell. October was again very dry, only about  $\frac{1}{2}$  inch of rain falling during the month.

Sampling stations were set up at a distance of 3 feet from the trunks of two bearing McIntosh apple trees on each of these three soils in the Cornell University orchard.<sup>2</sup> At every sampling station permanent sampling "wells" were placed at depths of 1, 2, 3, 4, 5, and 6 feet.<sup>3</sup>

## RESULTS

Fig. 1 presents comparisons of the average oxygen percentages in soil gas from the same depth in the three soils during the most of 1938.<sup>4</sup> Each point on each curve represents the average of the percentages of oxygen in the two wells on the same soil type at the depth and time designated.

While in all three soils the percentage of oxygen decreased as the depth of sampling increased, the effect was very much more marked on the silty clay soil than on the sandy loam soil, and the light silty clay loam soil was intermediate. Thus it is seen in Fig. 1 that at the 6 foot depth, oxygen varied from about  $14\frac{1}{2}$  per cent to about 20 per cent in the sandy loam soil. In the silty clay soil it was impossible to obtain samples at all between November 27, 1937 and June 14, 1938 and when a sample of gas was obtained, on June 14, it contained only 0.1 per cent oxygen. The oxygen then rose to a maximum of about  $11\frac{1}{2}$  per cent in mid-September and dropped abruptly following the heavy September rains. In the light silty clay loam soil at a depth of 6 feet it was possible to obtain gas samples after the first of April, 1938, but there were not appreciable quantities of oxygen in them until June 10. Then the oxygen rose rather steadily, reaching a maximum of about  $16\frac{1}{2}$  per cent in mid-September, but it did not drop much after the September rains.

While the sandy loam soil had high percentages of oxygen throughout both the dormant season and the growing season at all six depths there were rather protracted periods when oxygen was low or absent at depths below 1 foot in the heavier soils with less non-capillary porosity. The main differences in oxygen percentage between the two heavier soils were: (a) at a depth of 2 feet there seemed to be a considerable amount of oxygen throughout the year in the light silty clay loam whereas in the silty clay anaerobic conditions prevailed between the end of November 1937 and mid-April 1938. (b) At the 4, 5,

<sup>2</sup>Some preliminary studies indicate that at a distance of 3 feet from the trunk of the tree the oxygen percentages are as high as or are higher than they are farther away from the trunk where root population may be less dense, and soil moisture may be greater during the growing season.

<sup>3</sup>The use of sampling "wells" which makes it possible to obtain gas samples from dense subsoils rather high in moisture, has been investigated thoroughly and is discussed in another publication (5).

<sup>4</sup>The authors recognize the limitations of the "static" method for determining the potential oxygen supplying power of a given soil mass; but they believe that, incomplete though the picture may be, the percentages of oxygen found in samples of soil gas taken from a single location at relatively short intervals of time give a general idea of the seasonal changes in opportunity for aerobic respiration by roots at that location.

and 6 foot depths the oxygen percentage did not decrease very markedly in the light silty clay loam soil after 6½ inches of rain in mid-September 1938, whereas there was a very marked decrease of oxygen in the silty clay soil after the September rains.

Since the growing season was dry it seems likely that the difference of oxygen level and of duration of the period of aerobic conditions in the two heavier subsoils was less marked than it would be in normal or wet seasons, though that remains to be established by future work.

Fig. 2 shows the seasonal trend of carbon dioxide percentage in gas

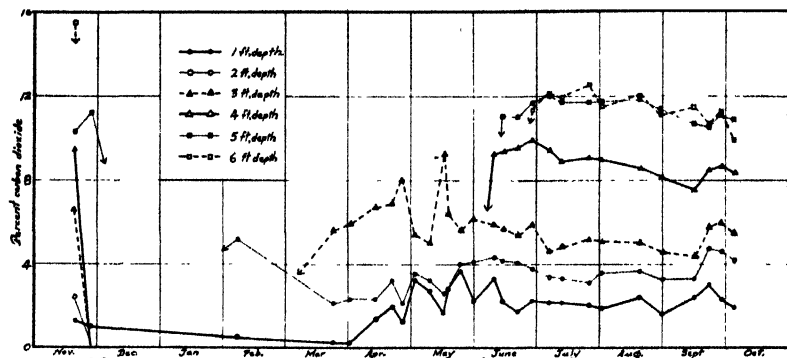


FIG. 2. Seasonal changes of carbon dioxide percentage at different depths in a silty clay orchard subsoil

taken from the six depths at one of the sampling locations in the silty clay orchard subsoil. It is clear that the carbon dioxide percentage increased materially as the depth of sampling increased. But the range of fluctuation at a given depth was less than the range of oxygen fluctuation, and there was no exact inverse relationship between oxygen and carbon dioxide percentage. In this soil and in the light silty clay loam soil a maximum value seemed to be attained at 13 per cent carbon dioxide, regardless of how low the oxygen per cent was. In the sandy loam soil a maximum carbon dioxide percentage of 3.4 was reached.

## DISCUSSION

If the work of De Villiers (8), which indicates that for apple seedling roots the lower critical concentration of oxygen is close to 5 per cent and the upper critical concentration is above 10 per cent is accepted as applying to mature apple tree root-systems under field conditions, it seems that the period of time during which apple tree roots can function in the lower layers of the silty clay soil may be rather short in a year of normal rainfall. Even in the light silty clay loam soil during a dry year below a depth of 3 feet the oxygen was less than 5 per cent for a period of 6 months or more, and was below 10 per cent for an additional 2 months or more. And since roots are known to exist below 3 feet in these soils, they must be essentially in "gas storage" during the dormant season and part of the growing season in

normal years. This would definitely restrict root activity during that time, even if the roots were not "resting".

The data indicate the significance of the non-capillary porosity of a soil layer in determining whether or not it will have a continuous supply of oxygen sufficient for normal root activity.<sup>5</sup> Considering the situation at a depth of 4 feet, it seems probable that a non-capillary porosity of about 16 per cent, that in the sandy loam soil, may be great enough to permit a satisfactory exchange of soil gases with those of the outside air throughout all years. It seems probable that a non-capillary porosity of about 1 per cent, that of the silty clay soil, may be insufficient for good aeration during part of many growing seasons. And it seems possible that a non-capillary porosity of about 7 per cent, that of the light silty clay loam soil, may permit satisfactory exchange of gases with the outside air during most growing seasons. If that is true, and the relationship between the percentage of non-capillary pore space and oxygen level is causal, the critical range of non-capillary porosity may prove to be between 7 and 1 per cent, insofar as the opportunity for aeration is concerned. This is already suggested by the work of Baver (1) and others.

The effect on root activity of the accumulation of carbon dioxide found in these subsoils is not yet definitely known. But the work by Cannon (7) and others has indicated that less than 25 per cent carbon dioxide has no measurable effect on root activity. Since the maximum percentage of carbon dioxide found was far less than that, it may not have been great enough to influence root activity appreciably.

The authors acknowledge the guidance and criticism of Dr. A. J. Heinicke and the preliminary work of Dr. R. W. Cummings.

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<sup>5</sup>The non-capillary porosity may prove to have more significance in the Northeast, where compact subsoils can remain close to their field capacity throughout many growing seasons, than under irrigation conditions of the semi-arid west.

## Contour Planting and Terracing as a Basis for Soil and Water Conservation in Orchards

By J. T. BREGGER, *U. S. Soil Conservation Service,*  
*Upper Darby, Pa.*

**F**RUIT growers as a class have been very careful about selecting favorable sites for their orchards and vineyards, at least from the standpoint of good soil and air drainage. This very situation, especially when accompanied by prolonged cultivation so common in the case of certain stone fruits, has brought about an excessive erosion problem. In fact, because of the annual and long season cultivation found in many orchards and vineyards, it constitutes the most serious erosion problem found in some agricultural areas today, not only cutting yields and the productivity period of the existing plantings, but destroying the sites at least temporarily for the next orchards or field crops which might follow.

The contour planting and terracing of vineyards, if not of orchards, is an Old World practice going back for several centuries in such locations as the Rhine lands of Germany. Presumably it was a natural consequence of planting vines or trees on steep slopes where, to hold the rainfall and even the soil itself, bench terraces were developed. The idea of terracing itself, of course, goes back much further in various parts of the world, but its adaptation to orcharding is of much more recent origin.

It is not clear just when the first contour planting of vineyards or orchards occurred in America. Undoubtedly there were some small plantings on or near the contour made by the early settlers from certain foreign countries where this practice had been in vogue.

What may be the first commercial contour orchard in this country was planted in 1895. Interestingly enough this citrus grove, laid out on an irrigation grade (almost true contour) near Uplands, California, by a civil engineer, is still being successfully managed by this same man. Other contour plantings were made during the early development of citriculture in California where rather steep slopes were chosen for frost freedom and designed for irrigation, but it was not until 1918 that this practice received any widespread recognition and encouragement under an orchard service agency directed by H. E. Reddick.

In the Southeastern States, where contour planting is now common, the practice originated about 1903. In fact, the oldest contour and terraced peach orchard in South Carolina, now 35 years old, is not yet abandoned. In a recent letter, E. H. Rawl, Extension Horticulturist, states that only 20 to 25 per cent of the present South Carolina peach acreage is *not* on the contour. Although it is intimated that the few earliest examples of this new planting practice were a result of individual initiative or imagination, it is highly significant that according to McHatton<sup>1</sup> the first bulletins published from the Georgia College of Agriculture on both peaches and apples suggested and recommended contouring and terracing.

<sup>1</sup>Letter to the author dated November 17, 1938.



Of interest is the fact that in the northeastern part of the United States we find our next example of contour orchard planting. Dr. M. B. Waite, recently retired United States Department of Agriculture Fruit Pathologist, back in 1907 made his first contour planting of apples and peaches near Odenton, Maryland. Since that time he has made additional contour plantings of many plants ranging from peach trees to daffodils. In 1908 Charles E. Bryan of Harford County, Maryland, set out a contour apple orchard on a 40 per cent slope. Bench-like terraces were built up along the contour rows as a result of soil movement toward the trees accomplished by cultivation. A 60-acre contour and terraced planting of apple trees was made by Lawrence Lee (also an engineer) near Leesburg, Virginia, in 1921. Throughout the Northeast these three mature orchards offer about the only time-tested examples of the effectiveness of orchard terracing with contour planting that can be found. There are in addition, however, several contour-planted and terraced vineyards in New York which go back over 20 years and show equal effectiveness and stability.

According to Yarnell,<sup>2</sup> the first contour orchards were planted in Texas between 1910 and 1922. Ness, in Texas Agricultural Experiment Station Bulletin No. 293, advises "terracing before planting and also that the rows should conform to the terraces". A few bearing or mature contour orchards may also be found in Arkansas where, as in Texas, the recommendations usually come through the Extension Service.

In the Central States there have been few instances of contour planting, but two have been given rather important recognition. One of these planted about 1910 in the vicinity of Columbia, Missouri, was visited annually by Dr. Whitten and his horticultural students. More recently the bench-terraced apple orchard laid out by Stark Brothers Nurseries and Orchard Company in 1921 in eastern Missouri has attracted considerable interest, due particularly to the fact that the terraced rows went completely around a conical hill.

Although no accurate survey has yet been made over the entire United States, the present area of contour fruit plantings is close to 50,000 acres. South Carolina alone accounts for about 15,000 acres of this total.

#### TYPES OF ORCHARD TERRACES

Because of the variation in rainfall, slope, soil, and other conditions in the different sections of the country, a variety of both types and systems of orchard terraces are in use at the present time.

First of all, terraces may be differentiated on the basis of grade, of which there are three general types: level, diversion grade, and irrigation grade. The first type is invariably in use where complete conservation of rainfall is desired. This may be the case in apple orchards where a permanent vegetative cover is maintained or in sections where semi-arid conditions prevail. Level terraces are also adapted to short rows and in cases where a well drained or porous soil, with or without

<sup>2</sup>Letter to the author dated November 9, 1938.

auxiliary protection, decreases the likelihood of over-topping under heavy rain intensities

The diversion grade terrace is the type most commonly used in the humid sections, particularly for cultivated orchards where the tree rows are rather long. Diversion grade terraces may vary from practically level to 1.0 per cent in fall, depending upon interval, length and soil factors. In the irrigation grade terrace, the use of which is almost entirely confined to California at the present time, the fall will run up to about 3 per cent. Such terraces also serve as diversion terraces during the rainy season, at which times the presence of orchard cover crops slows up the rate of flow and usually prevents damage by scouring.

Diversion terraces have been occasionally installed in existing square-planted orchards largely as a makeshift practice to protect long slopes from the damaging effects of excessive and concentrated runoff. In addition to making the cultivation problem more complicated, this practice usually involves the removal or sacrifice of from 3 to 10 per cent of the trees, but has seemed more than justified on the basis of increasing the productive years of the orchard, as well as preserving the site for the next crop or orchard which will follow. In the English walnut orchards of western Oregon where the planting distance is much greater, the use of diversion terraces or ditches is often accomplished without sacrificing any trees whatever. Along this line it might be added that the use of temporary ditches (smaller and at closer intervals) is proving a very satisfactory method of preventing destructive erosion from the winter rainfall of that climatic area. These ditches after serving their purpose during the rainy season are cultivated out in the spring to be reconstructed the following fall about the same time the annual winter cover crop is sown.

From the standpoint of shape or cross-section, orchard or vineyard terraces may be characterized as bench, narrow-base or broad-base types. The bench terrace is the normal type where the slope is above approximately 15 per cent. On slopes less steep than that, terraces may be termed "narrow-" or "broad-base", depending upon their width or cross-section. In general the narrow-base type (with a 4 to 6 feet ridge) is most common for orchard use.

Terraces may be constructed before as well as after the planting of the contour orchard. This determines to a large extent whether the trees will be planted on the terrace ridges or whether the ridges will be built slightly above the tree rows and gradually or more rapidly bury the original tree roots on the up hill side. When terraces are built in a gradual process as a result of contour cultivation following the planting of contour rows, the mixing of subsoil with top soil and fertilizer elements in the form of artificial applications or turned under cover crops, the resulting soil is invariably very desirable for tree root and top growth as well as for moisture infiltration and conservation. The so-called "Reddick" (California) bench terrace is constructed in this manner covering a period of about 10 years. Starting with the tree rows on little more than plow back-furrows, such terraces will be 6 feet above each other on some slopes by the end of the 10 year period

when they usually reach a more or less permanent profile and size. The steep down slopes or "risers" of such terraces are usually maintained in permanent vegetation.

Depending upon their size and span of construction, orchard terraces may be built with implements ranging from a disc harrow or plow to a 10-foot blade terracer. When a plow is used, the channel is often enlarged by following with a V-drag, which is also desirable to throw the loose soil nearer the tree row where the ridge will be less apt to be broken down by other orchard machinery. Terraces may be constructed from both sides as in the case of the Mangum or broad-base type, or from the upperside only as is true with the so-called "Nichols terrace" common in the Southeast.

More than one type of system has also been used in the contour planting and terracing of orchards or vineyards. For instance, a terrace may exist for each and every tree row, which at the beginning or in time, depending on its size, will catch all runoff from the row middle above it. This is invariably the case in a system of bench and level terraces which are usually all of the same size whether constructed prior to planting the orchard or allowed to develop over a period of years. In contrast to that, we find the use of so-called "master terraces" usually of the diversion type which may be spaced at every second, third, or even fourth tree row, with the intervening rows, a portion of which may be point or spur rows, which invariably become "terraced" as a result of contour cultivation.

Another variation in planting systems has to do with the lining up of rows in the opposite direction from those on the contour. These have been "staggered" in some plantings by merely planting the contour rows at given tree intervals. In other orchards, however, the trees are also kept in line up and down the slope. Sometimes the contour rows change direction to the extent that it is impossible to line up in parallel all the rows in the other direction, in which case a radial system is employed. From the standpoint of planting distances, it is often recommended that the contour rows be spaced somewhat wider than in the square-planted orchard, but that the trees in the contour rows be placed correspondingly closer together.

#### AUXILIARY EROSION CONTROL

Although contour orchard planting in conjunction with proper terracing might provide adequate erosion control, it is sound orchard management to also employ certain other practices in the orchard for soil building and fruit production. In this connection cover crops and mulching should be considered. A vegetative cover which might be the previous hay crop can be left in the contour tree row middles as buffer strips; or if not already there, one can be planted. If instead the orchard is interplanted with a row crop such as strawberries or corn, the contour cultivation received by this crop will provide increased water storage, though row crops are not as desirable as close growing inter-crops such as alfalfa. As the trees become larger and the root systems spread into the row middles, the cultivation which should gradually increase the capacity of the terrace channel in each row will

also break up year by year a little more of the cover crop, finally resulting in completely cultivated middles. When this stage is reached, a good annual cover crop system will aid materially in preventing soil movement into the terrace channels as well as in maintaining a porous soil to promote water absorption. In older orchards where shading interferes with a good cover crop growth, mulching has proved a desirable substitute. Mulching of the terrace ridges has also been done to hold down weed growth and to aid in keeping them well stabilized at a desirable height to maintain sufficient channel capacity.

### EFFECTS OF CONTOUR PLANTING AND TERRACING

Although experimental data are yet rather limited as related to the more fundamental effects of contour cultivation and terraces on fruit plants and the soil, certain observations have been made which should be of interest. On the favorable side of the picture it has been definitely shown that soil and water conservation has been accomplished by terracing. It has also been noted that young trees in practically all cases make a superior growth when planted on terraces which are built largely of topsoil.

When an enlargement of the terrace takes place during a period of several years, the addition of a considerable layer of soil over the original tree roots has not proved harmful to the trees. Evidently the roots grow into this new soil layer and probably have an even greater feeding area than formerly. The terracing of existing orchards, where gullying was about to result in abandonment, has brought about an immediate stabilization of the orchard site and materially prolonged the productive life of the trees. The economy of contour orchard operations might also be mentioned as definitely favorable.

On the other hand, a few less desirable features in connection with contour planting have been observed here and there which should be mentioned. In some cases, these are the reactions of fruit growers who are utilizing this practice for the first time and who naturally find certain inconveniences they have not yet learned to cope with. One-way cultivation in itself is repulsive to many fruit growers who have been taught that weeds or other vegetation left in the orchard during the cultivation period is nothing short of a disgrace. There is also the problem of spur rows, those short or point rows which, since they do not run the entire distance of the orchard, are particularly unhandy from the standpoint of spraying. A stationary spray system would solve this problem. Also in relation to spraying or dusting with the wind, there is the problem of a change in row direction when contour planting is done on certain sites. As a rule, however, most of the foregoing objections can be answered by asking which is "the lesser of two evils", and the practice which really "saves" the orchard or vineyard usually wins out.

### RESEARCH NEEDED AND UNDER WAY

Because of the far-reaching importance of the orchard and vineyard erosion problem and the widespread application of contour planting and terracing in meeting this problem, there is a real demand for some

fundamental research along this line. For one thing, the moisture relationships of terraces of different sizes and profiles should be studied from the standpoint of where the trees should be located; also whether a cover crop will offer less competition under these conditions. There may even be differences in fertilizer requirements, where all that is put on is conserved for the use of the trees. There should be some definite data on the effectiveness of contour planting and terracing in increasing fruit production. Another problem for study is the effect of non-cultivated terrace ridges or down slopes, whether in permanent vegetation or mulched, on the curculio and rodent problem.

Studies touching some of those problems are already underway. At the Hammondsport, New York, Soil and Water Conservation Experiment Station, a new contour- and bench-terraced vineyard has been planted on a steep slope where the soil moisture is being studied under mulched and unmulched ridges. In addition there are adjoining blocks of bearing vineyard, one planted and cultivated on the contour while the other is planted and cultivated up and down the slope, from which water runoff, soil loss, and production records have been taken for 3 years. A summary of these data which show a decided advantage in favor of the contour block is given in the Table I.

TABLE I--EFFECT OF CONTOUR CULTIVATION IN NEW YORK VINEYARD<sup>1</sup>  
(ELVIRA VARIETY, SLOPE 25 PER CENT, PLANTED 1910)

Year	May to October Rainfall (Inches)	Up and Down Cultivation			Contour Cultivation		
		Yield (Pounds)	H <sub>2</sub> O Loss (Inches)	Soil Loss (Pounds)	Yield (Pounds)	H <sub>2</sub> O Loss (Inches)	Soil Loss (Pounds)
1935	27.2	5,748	—	—	5,944	—	—
1936	12.4	1,044	211	3,093	2,124	029	72
1937	16.4	5,372	054	176	7,876	011	10
1938	10 ±	2,256	—	—	3,464	—	—

(Plots 225 × 48 ft) Yields, water and soil losses computed on acre basis.

Another study relating to the moisture content at various locations in the terrace is being initiated by the Service in cooperation with the Pennsylvania State Experiment Station in southern Pennsylvania. Evaluation surveys on Soil Conservation Service Operation Projects in various parts of the country have also been set up to determine as far as possible effective size and interval of orchard terraces under various soil types and auxiliary erosion control practices, and to evaluate several satisfactory and economical methods of building terraces in the orchard where the fruit grower is using ordinary farm or orchard machinery.

<sup>1</sup>Preliminary report (1938) by Dr. John Lamb, Jr., Project Supervisor, Soil Conservation Research

# The Influence of Cultural and Environmental Conditions on the Content of Organic Matter in Orchard Soils<sup>1</sup>

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State College, Penn.*

**E**IGHT years ago Jenny (7) stated that "climate exerts a dominating influence on the amount of total nitrogen in the soil." He also said, "Speaking in general terms, it may be said that for each fall of 10 degrees C in annual temperature the average nitrogen and organic matter content of soils increases two to three times." In the same publication Jenny added: "The nitrogen content of cultivated grassland soil located along an isotherm increases logarithmically with increasing moisture factors."

Although Jenny recognized, in dealing with the microbiology of the soil, that the climate of the soil was the controlling factor, rather than the climate of the air, the lack of records of soil climate made it necessary for him to use records of the climate above the soil. Fortunately, there seems to be a close correlation between these two. Since soil moisture is influenced by both rainfall and evaporation, Jenny suggested the value of the precipitation-evaporation ratio in these studies, but, because of the limited range of evaporation records available, he used the ratio of precipitation to the absolute saturation deficit of the air.

Nearly 10 years before the publication of Jenny's paper, Livingston and Shreve (8) stated: "The role of the soil in maintaining a water supply for plants is of vastly greater importance to them than any of the other roles which it plays. Although the texture of the soil is of prime importance with relation to penetration, movement, and conservation of a water supply for plants, it is fundamentally the climatic elements of rainfall and evaporation that determine what the soils of a given texture are able to do in presenting a moisture supply of a given amount. We are compelled, therefore, to regard the soil as a medium through which the climate acts upon plants."

No doubt if Livingston and Shreve were to write that paragraph today they would place more importance on transpiration as a function affecting the utilization of the available water supply and perhaps somewhat less emphasis on evaporation. Nevertheless, this possible change in emphasis could not detract from the importance they give to the ability of climate to modify plant growth through its effect upon the soil.

In our study of soil moisture conditions in Pennsylvania orchards, much of which is carried on in cooperation with the Soil Conservation Service of the United States Department of Agriculture, we have become convinced that, while soil texture is a matter of great importance in the penetration of moisture to the lower soil strata, the

<sup>1</sup>Authorized for publication on January 3, 1939, as paper No. 884 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

physical condition of the surface and the structure of the upper inch or two of the soil is frequently the controlling factor in the absorption of rainfall and consequently in the building up of the soil moisture supply. The growth of the cover and the organic content of this upper soil layer profoundly modify the degree of penetration of rainfall, especially when this rain comes with the intensities common to summer thunder showers.

In one of the research orchards at State College, catch basins have been installed to study soil and water losses under different cultural conditions on a slope ranging from 5 to 7 degrees. On July 3, 1936, during a rainfall of .77 inches in 15 minutes which reached an intensity of 3.84 inches per hour, a plot under annual cultivation with a cover crop seeded each June lost 20 per cent of the rainfall and nearly 600 pounds of soil per acre even though the cover crop was well established. The adjacent plot which was in sod that had been checked by heavy spring cultivation had no losses of soil or water. A plot which was seeded both fall and spring lost 34 per cent of the rainfall and 1,373 pounds of soil.

Havis and Gourley (6) studied the effects of mulch, sod, and cultivation on the penetration of water into the soil and concluded that both mulch and sod increased the porosity of the soil to a marked degree. Baker (1) reached much the same conclusions.

In the clay loam soils at State College, Pennsylvania, any material loss of organic matter through cultivation has resulted in puddling of the surface during summer rains and such a large run-off that cultivated plots have suffered seriously from drought while sod plots have had enough soil moisture for both trees and sod. These differences in moisture penetration are caused primarily by the growing cover, but also by the change in soil structure brought about by the decomposing cover. When cultivation destroys the cover the organic content of the soil assumes prime importance in furthering rainfall penetration.

In horticultural research we have been intent on working with conditions that were so similar throughout a considerable area that we could all agree on the results secured. We have not placed sufficient emphasis upon the importance of climate in creating dissimilarities, especially in experiments dealing with orchard soil management. The normal daily mean temperature at Norfolk, Virginia, is 59.5 degrees F, at Lynchburg, Virginia, 57.6 degrees, at State College, Pennsylvania, 48.5 degrees, at Ithaca, New York, 47.4 degrees, and at Burlington, Vermont, 45.1 degrees. From southeastern Virginia to New Hampshire the precipitation-temperature quotient increases from about 75 to over 180. The interaction of these two variables results in large differences in the possible organic matter content of the soil.

In such studies as this, Livingston and Shreve prefer to use a temperature factor more closely associated with the physiology of the plant than the mean annual temperature. Using the summation of temperatures above 32 degrees F for the average frostless season, they place this geographic range extending from southern Virginia to Maine and New Hampshire in two zones with the cumulation of temperature ranging from 12500 to 2500 degrees F (8). From south to north in

this same region there is a decrease in the number of frostless days of approximately 60 days.

The organic content of a soil is a function not only of the climate but also of the cultural treatment to which it has been subjected. Land long continued in sod approaches a maximum organic content for that soil and climate. Losses from this maximum are in proportion to the extent of cultivation. This decrease is illustrated in the Jordan soil fertility plots at State College, Pennsylvania. These have been continued without major change since 1881. Except for the fertilizer or manure additions, all plots have had a common treatment, a 4-year rotation of corn, oats, wheat, and mixed hay. Bordering each plot is a narrow sod strip which has been undisturbed throughout the experiment. The average composition of the soil under these sod strips after 41 years showed 3.96 per cent organic matter (0.1877 per cent total nitrogen). The unfertilized plots had over 25 per cent less organic matter in the soil than in the adjoining sod strips. Even the plots which had received 12 tons of manure per acre each rotation had 12 per cent less organic content in the soil than that under the sod strips along side (15).

This interaction of climate and culture on the nitrogen content of the soil is further illustrated in a study at State College, Pennsylvania, of the inter-relation of soil organic matter and fertilizer nitrogen on the growth of apple trees. Forty-two steel cylinders, 5½ feet deep and 5 feet across were sunk in the ground in six rows, each of seven cylinders. In 1928 these were filled uniformly with soil from an area in one of the College orchards into which there had been some surface wash but which had been in sod for a number of years. This soil contained in the upper 7 inches 3.141 per cent organic matter (0.1205 per cent total nitrogen). An apple tree was planted in each cylinder. The first row received no fertilizer nitrogen; the next row a single unit of nitrogen; the next, two units, with each row beyond receiving increasing amounts of nitrate of soda or sulphate of ammonia. The first cylinder in each row received no additional organic matter. The second had one unit of green cover crop, grown in similar soil, chopped fine and spaded into the soil. Each cylinder down the row received increasing amount of chopped rye or millet.

In 1932, through the cooperation of Professor J. W. White of the Department of Agronomy<sup>2</sup> the soil in each cylinder was analyzed for organic content. After five seasons the cylinders showed a surprising uniformity of soil. The number 1 cylinders, which received no organic matter, averaged 2.201 per cent organic matter content as did the number 2 cylinders. Although the number 7 cylinders had received chopped green covers totaling over 11 tons per acre, they averaged only 2.327 per cent soil organic matter, about 25 per cent less than in the original soil. Similar analyses made in 1934 showed very little additional change. The soil in each cylinder apparently had come into equilibrium with the factors of climate and the cultural system.

If these general conditions are fundamental then we should expect

<sup>2</sup>Throughout most of its studies of problems dealing with orchard soil management the Department of Horticulture has had the benefit of close cooperation with Professor White. His council and criticism in the preparation of this paper is gratefully acknowledged.



considerable differences in soil organic content from regions materially colder or warmer than State College and from those wetter or dryer. Do these differences exist and also are they large enough materially to modify the conclusions from experiments otherwise comparable? In such a critical review we should again emphasize the fact so well stated by Sievers and Holtz (13) over a decade ago that "the amount of organic matter found in any soil is the resultant of accumulation and of loss through decomposition, both of which factors are decidedly influenced by climatic conditions as they exist in nature or are modified by man". We should add to this the fact that this "resultant" does not reach an equilibrium for several years after a particular cultural system is established.

For regions colder than State College, Pennsylvania, Collison *et al.* (3, 4), in commercial orchards and in lysimeters at Geneva, New York, found higher nitrogen values in the surface soil than under comparable conditions at State College. Cummings (5), reporting on 93 Baldwin orchards in New York, found an average soil organic matter content much higher than that under the sod strips in the Jordan plots. Lyon and Wilson (9) also reported total soil nitrogen higher under sod and under cultivation at Ithaca, New York, but not as high as Collison found on a much more fertile soil. Field A at Amherst, Massachusetts, since 1883 has been in fertilizer trials somewhat similar to those in the Jordan plots. The total nitrogen and organic matter content of the surface soil of Field A is about 30 per cent higher than in similarly treated areas in the Jordan plots.

Records of soil composition from regions warmer than State College, but not too distant, are limited. Baker (1), in an apple orchard near Lafayette, Indiana, which had been in blue grass for 10 years with annual applications of nitrogen, found 2,413 pounds of nitrogen per acre 8 inches deep. (The soil under the sod strips in the Pennsylvania Jordan plots had 3,754 pounds 7 inches deep.) Blair and Prince (2), with a Sassafras loam in New Jersey, found that 25 years of a 5-year rotation reduced the nitrogen content of the surface soil to about 0.08 per cent. In a Cecil sandy soil near Raleigh, North Carolina, 8 years of alternate corn and cotton with winter green manure crops, but without fertilizers, resulted in 0.03 per cent nitrogen in the surface soil (16). In a Florida orange grove on Norfolk medium fine sand, 10 years of cultivation reduced virgin land to 0.01 per cent nitrogen in the surface soil (14).

Are these possible differences from climate large enough to make their consideration necessary in a territory as nearly homogeneous as that covered by the northeastern states, those from Maryland to Maine? Certainly many indications point that way. For some time at least, this will have to be a matter of opinion only; records are too few for a more definite answer. At least it would seem highly desirable to secure more complete climatological data for our main experimental areas and to establish a more uniform system of reporting soil nitrogen and organic matter so that at some time in the future we may reach a better understanding of the interrelation of climate, culture, soil and tree growth.

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# Studies of Top and Root Growth of Young Apple Trees in Soil and Peat-Soil Mixtures of Varying Moisture Contents<sup>1</sup>

By H. B. TUKEY and K. D. BRASE, *New York State Agricultural Experiment Station, Geneva, N. Y.*

AMONG the attempts by the authors to find ways in which to overcome the slow starting and poor growth of fruit trees the first year they are set in the orchard (5, 6, 7) has been the use of German granulated peat moss mixed with the soil thrown back into the tree hole at planting. The results were at once significant (7) and subsequently have been generally successful in improving the stand and growth of young trees so treated.

There has, however, been some difference in the response during different seasons. During seasons of plentiful rainfall in early spring the improvement from the use of peat moss has been the greatest, while in a very dry season no appreciable gain in top growth has been observed. However, root development has been greater both in amount and extent in all cases where peat moss has been used, regardless of season.

In order to study the growth of trees more critically and under controlled conditions and in order to shed more light upon the factors underlying the improvement in growth, the test here reported was undertaken.

## MATERIALS AND METHODS

Fourteen 2-year-old McIntosh apple trees on Malling I rootstocks were used. Both the rootstocks and the trees were propagated on the Station grounds and were selected from several hundred for uniformity in size, weight, height, trunk diameter, number and shape of branches, and amount and spread of roots. The photographs and the figures in the tables indicate how successful was the attempt to secure uniform trees.

Wooden boxes, having an internal measurement of 13½ inches on a side, were used, in which to plant the trees. The front side of each box was made removable and a sheet of glass placed for root observation. The glass was kept covered by the wooden side except during observations.

The soil was Ontario loam taken from the area where the field trials with peat had been conducted. This soil is of good fertility and inclined to be heavy. The peat moss was imported granulated German peat moss. In filling the boxes and planting the trees, 2 cubic feet of loose soil was used for each box containing no peat moss, and 1 cubic foot of soil and 1 cubic foot of peat moss for the peat-soil mixtures. The

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<sup>1</sup>Journal Paper No. 311 of the New York State Agricultural Experiment Station.

trees were planted on February 17, 1938 and started in a cool greenhouse (50 degrees F).

The treatments were such as to compare soil and peat-soil mixtures under conditions designated "medium" moisture, "dry", and "wet", as follows:

- Box 1 and 1A—soil (medium moisture—check)
- Box 2 and 2A—peat-soil (medium moisture—check)
- Box 3 and 3A—peat-soil (dry)
- Box 4 and 4A—peat-soil (wet)
- Box 5 and 5A—soil (wet)

"Medium" moisture content was that which placed the soil in good physical condition for planting as judged by common horticultural practice. "Dry condition" was that which contained a trifle less moisture. "Wet condition" was that which was considered excessively wet. Further discussion of this phase of the work is left to the discussion of results.

In addition, two boxes were divided by a vertical partition, one half of each box containing a peat-soil mixture and the other half containing soil except for a pocket of peat moss about the roots. The only difference between the two treatments was that the two trees planted in one box (Box 6) were set close to the glass to better observe root action, while the two trees in the other (Box 7) were set in the center of the box.

The moisture contents were maintained by weighing the boxes at the beginning of the experiment and keeping them to this weight by watering as required. Once a week sufficed at the beginning of the test, and every other day later in the season.

Root development was studied by drawing on ruled paper the position of the roots against the glass several times during the season (2, 3, 4). Shoot length was measured several times, and leaf area was determined both by measurement of individual leaves early in the season and by measurement of the entire crop of leaves at the end of the growing season.

Soil atmosphere samples were taken by Dr. Damon Boynton by means of sampling tubes fixed permanently in the soil. At the completion of the experiment the trees were carefully removed, the soil collected and dried to oven-dryness and the moisture computed by subtraction.

#### EXAMINATION OF THE SOIL AND PEAT-SOIL MIXTURES

Table I gives the weight of soil used, its volume, volume weight relation, specific gravity, porosity, and both actual weight and percentage of water. From these figures has been computed the volume of soil, water, and atmosphere (Table I) for each soil and soil-peat mixture used.<sup>2</sup>

<sup>2</sup>The authors are indebted to C. S. Slater and E. A. Carleton of the Division of Research, of the Soil Conservation Service; the former for specific gravity determinations, the latter for the representation of the soil-water-atmosphere relation, and both for helpful suggestions.

TABLE I—VOLUME, WEIGHT, VOLUME WEIGHT, SPECIFIC GRAVITY, POROSITY, AND MOISTURE CONTENT OF SOIL AND PEAT-SOIL MIXTURES

Box Number	Treatment	Volume of Soil Measured After 90 Days in Box	Oven-Weight of Soil (Kg)	Volume Weight	Specific Gravity	Porosity $\frac{S-A}{S} \times 100$	Moisture Content	
							(Kg)	(Per Cent)
1	Soil (medium moisture) . .	51,653	57,210	1.107	2.82	57.7	11.058	19.32
1A		51,258	57,010	1.112	2.82	57.2	11.885	20.85
2	Peat-soil (medium moisture).	48,893	33,525	.885	2.48	72.3	13.905	41.47
2A		47,710	31,915	.869	2.48	73.0	15,822	48.53
3	Peat-soil (dry) . . . . .	51,653	33,870	.651	2.50	73.9	9,224	27.39
3A		50,884	32,460	.638	2.50	74.5	10,434	32.45
4	Peat-soil (wet) . . . . .	49,681	32,360	.651	2.51	74.0	17,366	53.66
4A		48,104	31,950	.664	2.51	73.8	17,748	55.55
5	Soil (wet)... . . . .	41,401	59,130	1.428	2.82	45.5	15,488	26.19
5A		42,978	61,300	1.426	2.82	45.8	13,346	21.77

\*Porosity is the percentage by volume of the soil which is unoccupied by soil particles =  $\frac{S-A}{S} \times 100$  S = specific gravity; A = volume weight

From these figures in turn has been computed the proportion by volume of soil, water, and atmosphere of each soil and peat-soil mixture. The results are represented graphically in Fig. 1. The diagram

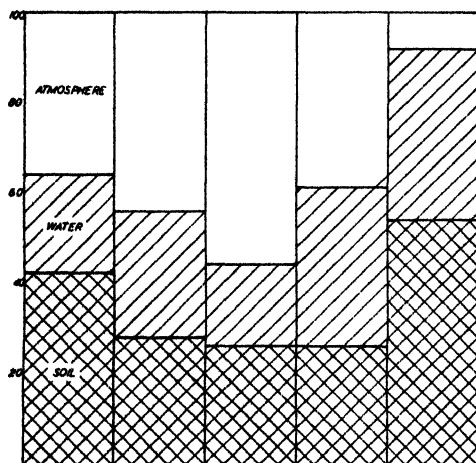


FIG. 1. Representation of proportion of soil, moisture, and atmosphere in each of the five treatments. 1, Soil (medium moisture); 2, Peat-soil (medium moisture); 3, Peat-soil (dry); 4, Peat-soil (wet); 5, Soil (wet).

gives a quick appreciation of the three factors, showing: (a) The proportion of water is similar in treatments 4-4A (soil-peat wet) and 5-5A (soil wet) but the atmosphere is relatively much smaller in the latter. (b) The atmosphere is similar in treatments 1-1A (soil medium moisture) and 4-4A (peat-soil wet) but the moisture is greater in the latter. (c) The moisture is not greatly different in treatments 1-1A (soil medium moisture) and 3-3A (peat-soil dry) but the atmosphere is greater in the latter.

#### ROOT DEVELOPMENT

It is difficult to make adequate record of root development and distribution. The drawings of roots against the glass in the boxes 92 days and 114 days after planting (Figs. 2 and 3) give an approximation of the rapidity of development of new roots and their distribution throughout the soil mass, while the photographs of the

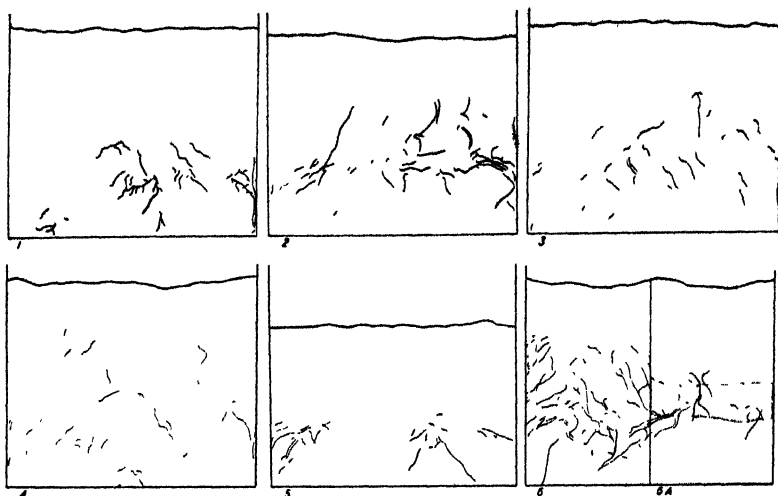


FIG. 2. Drawings of root development 92 days after planting, as seen through glass sides of boxes. 1, Soil (medium moisture); 2, Peat-soil (medium moisture); 3, Peat-soil (dry); 4, Peat-soil (wet); 5, Soil (wet); 6, Peat-soil (uniform mixture); 6A, Peat-soil (peat confined to a pocket).

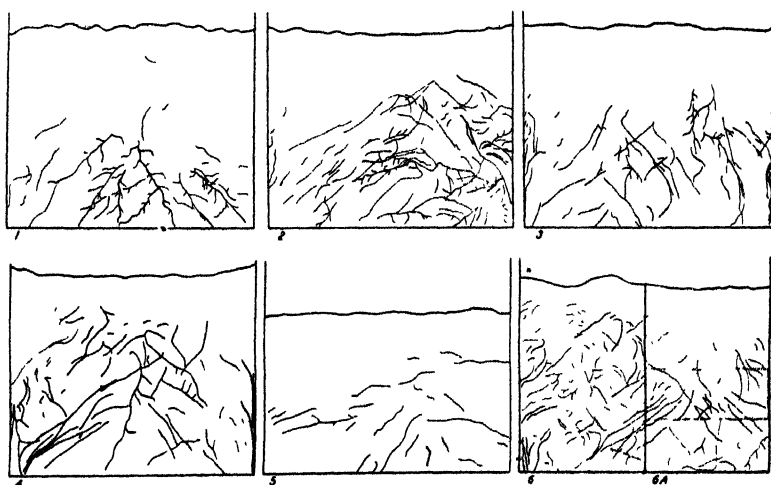


FIG. 3. Drawings of root development 114 days after planting, as seen through glass sides of boxes. 1, Soil (medium moisture); 2, Peat-soil (medium moisture); 3, Peat-soil (dry); 4, Peat-soil (wet); 5, Soil (wet); 6, Peat-soil (uniform mixture); 6A, Peat-soil (peat confined to a pocket).

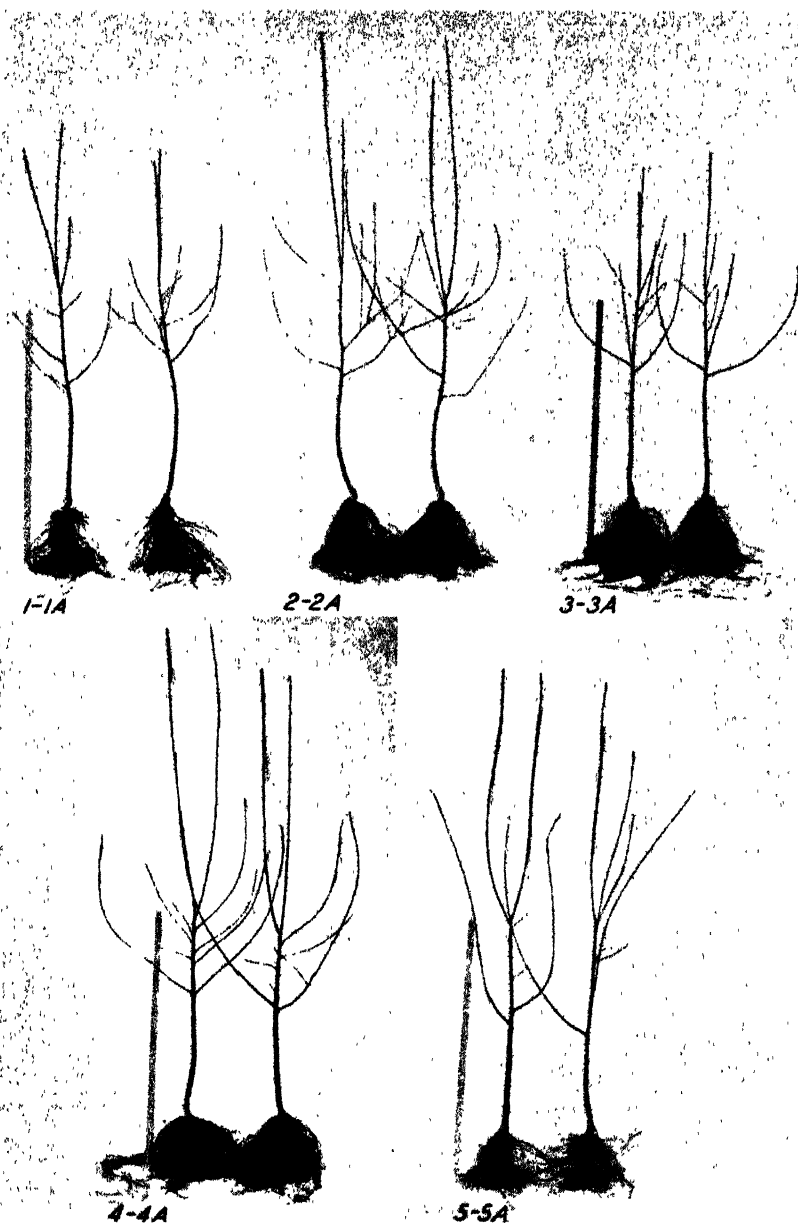


FIG. 4. Growth of trees in soil and peat-soil mixtures of varying moisture content (Metric rule in each photograph for size comparison). 1-1A—soil (medium moisture); 2-2A—peat-soil moisture (medium moisture); 3-3A—peat-soil mixture (dry); 4-4A—peat-soil mixture (wet); 5-5A—soil (wet).

TABLE II—CALCULATED VOLUMES OF SOIL, WATER, AND ATMOSPHERE

Box Number	Treatment	Volume of Soil* (Cc)	Volume of Water** (Cc)	Volume of Atmosphere†
1	Soil (medium moisture) . . .	21,835	11,058	18,780
2	Peat-soil (medium moisture) . . .	13,518	13,905	21,470
3	Peat-soil (dry) . . . . .	13,468	9,224	28,991
4	Peat-soil (wet) . . . . .	12,892	17,366	19,423
5	Soil (wet) . . . . .	22,568	15,488	3,345

\*Oven dry weight divided by specific gravity.

\*\*Directly from the weight.

†By subtraction.

trees at the end of the growing season (Fig. 4) give an approximation of the mass of the roots.

It will be seen at once that the initiation of new roots and the rapidity of spread and distribution were greatest in the peat-soil mixtures (2-2A, 3-3A, 4-4A). Where the trees were planted in soil with a pocket of peat around the roots, roots formed rapidly in the peat moss but did not extend far into the adjacent soil mass, while where the trees were planted in a uniformly mixed peat-soil mixture the spread and abundance of roots was greatly increased. Thus it appears that peat moss in itself favors early root development but that a uniform mixing of the peat and soil favors a much wider and better spread of roots.

It will be seen also (Fig. 4) that the mass of roots at the end of the growing season is greater in the peat-soil mixtures (2-2A, 3-3A, 4-4A) as compared to that in soil, irrespective of moisture content. The greatest root development is in treatment 4-4A (peat-soil wet), next in 3-3A (peat-soil dry), next in 2-2A (peat-soil medium moisture), next in 1-1A (soil medium moisture), and poorest in 5-5A (soil wet). The abundant root formation in 4-4A (peat-soil wet) as compared to the poorer development in 5-5A (soil wet) is particularly interesting. Likewise, the very good root development in 3-3A (peat-soil dry) is of interest, especially when considered in conjunction with the reduced top development.

The results agree closely with the results in the field in which the use of peat moss in planting has increased the abundance and spread of roots irrespective of whether the season was dry or wet. They agree also with the findings of Jacobs (2, 3, 4) working with shade trees.

#### SHOOT DEVELOPMENT

In field trials with peat moss, the time of bud start has often been earlier where peat has been used, but in the trials in the greenhouse here reported there were no significant differences. The differences were mostly in the number of buds which started and in the rate and duration of shoot elongation.

As with the results in field trials, the number of growing points was increased in the peat-soil treatments, the increase occurring in the buds near the bases of lateral branches. Table III shows the greatest number of shoots in the soil-peat mixture (moderate moisture), next in the soil-peat mixture (wet), next in soil (moderate moisture), next in the soil-peat mixture (dry), and least in soil (wet). Trees 4-4A compared with 5-5A in Fig. 4 picture the differences very well.



TABLE III—NUMBER OF SHOOTS AND EARLY SEASON AND TOTAL SHOOT GROWTH

Box Number	Treatment	Number of Shoots	Shoot Length (Cm)				
			92 Days After Planting	Rate of Elongation 92 Days After Planting	End of Growing Season		
1	Soil (medium moisture)	11	171	209	Ceased	263	574
1A		11	138			311	
2	Peat-soil (medium moisture)	12	231	485	Continuing	540	1084
2A		10	254			544	
3	Peat-soil (dry)	11	164	315	Ceased	372	625
3A		9	151			253	
4	Peat-soil (wet)	12	281	548	Continuing	715	1281
4A		9	267			566	
5	Soil (wet)	8	146	266	Slowly but later continuing	399	827
5A		8	120			428	

The greater rapidity of shoot elongation of trees in the peat-soil mixtures in early season is shown by the measurements in Table III of shoot length 92 days after planting. All three of the peat-soil treatments show superior growth than either of the soil treatments even though one of the peat-soil treatments provided subnormal moisture. The greatest growth is seen to be in the peat-moss mixture having excess moisture while the poorest growth is in the soil having excess moisture. These figures give a better idea of the increased growth in the peat-soil mixture than do the later season measurements for the reason that later in the season the roots reached the sides of the boxes and provided conditions more favorable to growth.

There is normally a slackening or even cessation of shoot elongation in mid-summer, and the formation of terminal buds. These buds may or may not develop a second or later season elongation, but frequently do not. In field tests it has been observed that growth of peat-treated trees does not slow so early. Similar observations were made in the greenhouse, the cessation of growth and formation of the terminal buds occurring about 92 days after planting. Treatments 1-1A (soil medium moisture) and 3-3A (peat-soil dry) ceased elongation as trees do commonly in the field. Treatments 2-2A (peat-soil medium moisture) and 4-4A (peat-soil wet) continued elongation several weeks later. Treatment 5-5A (soil wet) slowed down about 92 days after planting and then made a second terminal growth as trees commonly do in the field following late season rains.

The total growth at the end of the season, also given in Table III, reflects the combined effect of number of growing points and rapidity and duration of elongation. Nearly the same general order is found for the treatments as with early season growth, excepting that the treatment 5-5A (soil wet) has moved from last place to third and now precedes both treatments 3-3A (peat-soil dry) and 1-1A (soil medium moisture). This, as has been pointed out, is due to the continued elongation due to an abundance of moisture and not to greater number of growing points or to more rapid early season elongation. The best growth is found in treatment 4-4A (peat-soil wet), followed rather closely by treatment 2-2A (peat-soil medium moisture).

## LEAF AREA

The data of leaf area are given in Table IV. The average size of the 10th to 12th leaf on the shoot indicates the early season performance, while the total leaf area includes both early and late growth. The early season development is important to single out for discussion because, as has been noted in the preceding paragraphs, some treatments continued late season growth.

TABLE IV—EARLY SEASON COMPARATIVE LEAF AREA AND TOTAL AREA AT END OF SEASON

Box Number	Treatment	Single Leaf Area (Sq Cms)	Entire Leaf Area (Sq Cms)
1	Soil (medium moisture)	21.78	4143
1A		20.04	3730
2	Peat-soil (medium moisture)	42.84	5203
2A		36.36	5273
3	Peat-soil (dry)	23.00	3650
3A		22.16	3551
4	Peat-soil (wet)	37.28	6296
4A		42.12	5694
5	Soil (wet)	30.52	5518
5A		27.24	4896

In general, the order of greatest early-season leaf size is correlated with greatest early season shoot elongation; and greatest total leaf area is associated with greatest total shoot elongation. An interesting point is the relatively small size of leaves in early season in treatments 1-1A (soil medium moisture), 3-3A (soil-peat dry), and 5-5A (soil wet), and the large size of leaves in treatments 2-2A (soil medium moisture) and 4-4A (peat-soil wet). At the end of the season treatment 5-5A (soil wet) shows a greatly increased total leaf area due to the second period of growth, during which large leaves are formed.

## TRUNK DIAMETER AND TOTAL WEIGHT

Table V gives the diameter increases of the trunks of the trees measured 5 cms above the unions, and the increases in weights of tops and roots combined, taken immediately after leaf fall. Both sets of figures agree generally with the general trend reported for leaf area and shoot development, in which the greatest increases occurred in treatment 4-4A (peat-soil wet) and the least in 1-1A (soil medium moisture). The former represents slightly more than twice the increase of the latter. Treatment 3-3A (peat-soil dry) is next poorest and is but slightly greater than 1-1A (soil medium moisture).

TABLE V—INCREASE IN TRUNK DIAMETER AND TOTAL TREE WEIGHT

Box Number	Treatment	Diam. at Planting* (Mm)	Increase in Diam. (Mm)	Weight at Planting (Kg)	Increase in Weight (Kg)
1	Soil (medium moisture)	13.2	3.6	227	.307
1A		12.7	3.8	.198	.397
2	Peat-soil (medium moisture)	13.2	6.8	.198	.596
2A		13.2	6.1	.191	.659
3	Peat-soil (dry)	12.1	4.9	.198	.426
3A		12.1	5.6	.198	.426
4	Peat-soil (wet)	11.7	10.3	.170	.794
4A		11.7	9.3	.198	.823
5	Soil (wet)	11.6	7.9	.227	.538
5A		12.1	5.9	.198	.482

\*Measured 5 cm above the union.

Treatments 2-2A (peat-soil medium moisture) and 5-5A (soil wet) compete for next to the largest increase. Measured by trunk increase, the latter is ahead, but measured by total weight the former leads. This is to be expected from the results previously given for root development, in which a small root development was shown for 5-5A (soil wet).

### ANALYSES OF SOIL ATMOSPHERE

A valuable addition to the data is supplied in Table VI, giving the oxygen and carbon dioxide contents of the soil atmosphere. The consistently highest  $\text{CO}_2/\text{O}_2$  ratio is found in the treatment 5-5A (soil wet), in which root development was the poorest. Also treatment 4-4A (peat-soil wet) with similar proportion of moisture as 5-5A shows a much lower  $\text{CO}_2/\text{O}_2$  ratio, indicating the improvement in aeration from the presence of peat moss. It has been suggested by Boynton, deVilliers, and Reuther (1) that there may be different critical concentrations of oxygen for different phases of root activity and that a relatively high oxygen content (12 per cent) may be critical for initiation of new roots whereas for subsistence the low level of 3 per cent may suffice.

TABLE VI—ANALYSES OF SOIL ATMOSPHERE AT A DEPTH OF 6 INCHES\*

Box Number	Treatment	Per Cent					
		June 11, 1938		July 1, 1938		July 22, 1938	
		$\text{CO}_2$	$\text{O}_2$	$\text{CO}_2$	$\text{O}_2$	$\text{CO}_2$	$\text{O}_2$
1A	Soil (medium moisture) . . . . .	2.3	18.5	1.5	19.5	1.2	19.3
2	Peat-soil (medium moisture) . . . . .	1.0	19.8	0.6	19.6	1.2	19.6
2A	Peat-soil (medium moisture) . . . . .	1.1	19.7	1.1	19.6	1.0	19.4
3A	Peat-soil (dry) . . . . .	0.5	20.3	0.2	20.4	0.6	20.1
4	Peat-soil (wet) . . . . .	1.4	19.6	1.4	19.4	1.9	19.9
4A	Peat-soil (wet) . . . . .	0.5	20.4	1.7	19.1	2.0	19.2
5	Soil (wet) . . . . .	3.5	13.6	4.1	17.3	4.5	10.4
5A	Soil (wet) . . . . .	3.5	12.2	3.4	18.2	4.2	12.3

\*All data through the courtesy of Dr. Damon Boynton, Cornell University.

### CONCLUSIONS

The incorporation of granulated peat moss with the soil has resulted in improved aeration of the soil, higher oxygen content and lower carbon dioxide content, particularly as compared with soil with excess moisture, and increased root development and spread, irrespective of excess, medium, or below medium moisture contents.

When early season moisture was excessive, both top and root growth were greatly increased. When early season moisture was medium in amount, both top and root growth were increased. When early season moisture was below medium, root growth was increased, but top growth was not.

When mid-season moisture was excessive, the relative increase in top growth was reduced. When mid-season moisture was medium or below medium, the relative increase in top growth from peat moss was increased.

Best results from peat moss were secured from conditions which simulate seasons of adequate or excessive early season moisture, followed by a below-normal mid-season moisture. It is suggested that several factors are involved in the benefit from peat moss, among them (a) better contact of roots with the soil moisture immediately after planting, (b) improved aeration in early season favoring rapid root development, (c) easier penetration of rainfall to the area occupied by the roots and less run-off of surface water, and (d) easier penetration of roots into a peat-soil mixture because of the decreased density.

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# Soils and Fertilizers in Relation to the Yield, Growth and Composition of the Coffee Tree<sup>1</sup>

By L. A. DEAN and J. H. BEAUMONT,<sup>2</sup> *Hawaii Agricultural Experiment Station, Honolulu, T. H.*

**H**AWAII produces annually approximately 10,000,000 pounds of green coffee on 5,000 acres. One of the dominant factors in this high production per acre has been the intensive use of commercial fertilizers. The first experiment on the relationship between fertilizers and the growth and yield of coffee trees in Hawaii was started in 1930; a second began in 1934. This paper summarizes the results of the two experiments.

There are, apparently, few data available on the quantitative responses of coffee trees to fertilizers. This is especially true for coffee grown without shade as is the practice in Hawaii. As early as 1913 Anstead and Pittock (1), on the basis of the ash analysis of the coffee bean, suggested that a fertilizer containing a preponderance of potash might be expected to aid a coffee tree in ripening and holding its crop. McClelland (5), working with shaded coffee trees in Puerto Rico, showed that applications of potash over a period of 8 years increased the yields and diameters of coffee trees. This was particularly true when potash was used in conjunction with nitrogen, although nitrogen alone adversely affected growth and fruiting. No responses to phosphate fertilizers were obtained.

## FIELD EXPERIMENTS

*Fukuda Experiment:*—The initial fertilizer experiment in the Kona District, Hawaii, was established in 1930 on the Fukuda farm, Kainaliu, at an elevation of 1,500 feet. This experiment was a 5 x 5 latin square with nine trees per plat and intervals of 9 feet between trees. The semi-annual fertilizer treatments, per acre, were as follows: check—no fertilizer; N—80 pounds of nitrogen; NP—80 pounds of nitrogen and 80 pounds of  $P_2O_5$ ; NK—80 pounds of nitrogen and 80 pounds of  $K_2O$ ; and NPK—80 pounds of nitrogen, 80 pounds of  $P_2O_5$ , and 80 pounds of  $K_2O$ .

The nitrogen was supplied half from ammonium sulphate and half from sodium nitrate, the phosphorus from super-phosphate, and the potash from potassium sulphate. This fertilizer was applied in February and July to the surface of the soil in a band about 4 feet in diameter around the tree. An attempt was made to eliminate cross feeding by maintaining trenches about 1 foot deep around each plat. At the time

<sup>1</sup>Joint contribution of the Departments of Chemistry and Soils and of Horticulture. Published with permission of the Director of the Hawaii Agricultural Experiment Station.

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the experiment was established the trees were about 5 years of age. The multiple-vertical system of training was used.

The average annual yields of the five treatments are given in Fig. 1. No significant differences were obtained until the third harvest (1932-33), but from then on very significant increases were noted in the plots receiving potash. In no year was there a significant difference between the NK and NPK plats.

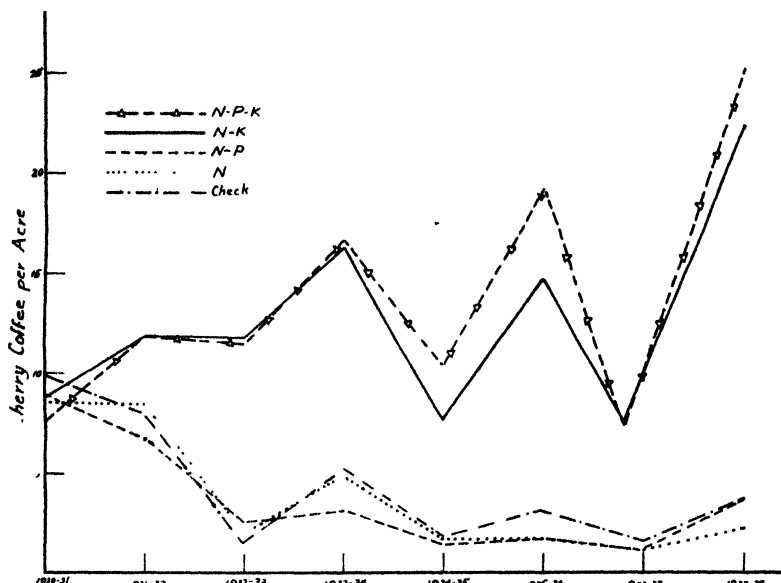


FIG. 1. Annual yields (in thousand pounds) of coffee cherries of differently fertilized plats of the Fukuda experiment.

An analysis of variance of the 8 years' yield data, using the procedure established by Inner *et al.* (4), is presented in Table I. It may be seen

TABLE I—ANALYSIS OF VARIANCE (FUKUDA EXPERIMENT)

Variation Due to	Degrees of Freedom	Sum of Squares	Mean Square	$\frac{1}{2}$ ln Mean	Z
Rows	4	3,154.75	789	3.3450	0.2143
Columns	4	8,091.25	2,023	3.8061	0.6754
Treatments	4	407,935.32	101,984	5.7663	2.6356
Years	7	122,991.66	17,570	4.8890	1.7583
Years $\times$ treatment	28	192,722.33	6,883	4.4184	1.2877
Years $\times$ rows	28	16,466.55	588	3.1884	0.0577
Years $\times$ columns	28	36,593.48	1,307	3.4720	0.3413
Error	96	50,338.15	524	3.1307	—
Total	199	838,293.49	—	—	—

that the mean square for years is highly significant, indicating that the average yields in different years were significantly different. The significantly higher mean square for years than for the interaction of

years x treatments shows that yields are different in different years irrespective of fertilizer treatments. Because the mean square for the interaction of years x treatments is significant, it is apparent that all treatments did not yield the same in different years. It may further be seen that the mean square for treatments is significantly greater than the mean square for years, indicating that the fertilizer treatments had a more pronounced effect than seasons in affecting yield. The mean square for treatments significantly exceeds the mean square for the interaction of treatments x years indicating that certain treatments are consistently different from others in most years. Consequently, the conclusion may be drawn that coffee trees fertilized with potash and nitrogen will give significantly greater yields but that great annual fluctuations in yield may be expected.

The seasonal effects in relation to the yield of coffee trees are discussed elsewhere by Dean (3) and Beaumont (2).

Commencing in 1937, a series of growth measurements of the trees of the differently fertilized plats was undertaken. These measurements included circumference of verticals, average annual lateral growth per tree, and average annual terminal growth. These data are summarized in Table II. It may be seen that both the squared circumferences and the lateral growth of the trees receiving potash were significantly higher than for those not receiving potash. No significant relationship was found between fertilization and terminal growth. The interrelationships between growth and yield have been previously discussed by Beaumont (2).

TABLE II—EFFECTS OF DIFFERENTIAL FERTILIZER TREATMENT ON THE GROWTH RESPONSES OF COFFEE TREES AT THE FUKUDA FARM

Treatment	1937-1938 Yield (Cwt/Acre)	1938 Squared Circumference per Vertical (Cm)	1937 Lateral Growth (Cm)	1937 Terminal Growth (Cm)
Check	38	11	24	29
N	22	10	22	29
NP	37	11	23	34
NK	223	21	32	33
NPK	252	23	30	28
Standard errors	10.3	0.97	0.84	1.8

*Takashiba Experiment* — The second fertilizer experiment was established in 1934 on the Takashiba farm, Kealakekua, at an elevation of 2,200 feet. This location receives more rainfall and less sunlight than does the Fukuda farm. Further the topped system of training had been used. The experiment consisted of three randomized blocks of five treatments in nine-tree plats. The fertilizers used in this experiment were derived from the same sources as in the Fukuda experiment, and the semi-annual treatments, expressed on the acre basis, were as follows: NP—80 pounds of nitrogen and 80 pounds of  $P_2O_5$ ; PK—80 pounds of  $P_2O_5$  and 80 pounds of  $K_2O$ ; NK—80 pounds of nitrogen and 80 pounds of  $K_2O$ ; NPK—80 pounds of nitrogen, 80 pounds of

$P_2O_5$ , and 80 pounds of  $K_2O$ ; and  $\frac{1}{2}$ NPK—40 pounds of nitrogen, 80 pounds of  $P_2O_5$ , and 80 pounds of  $K_2O$ .

The average annual yields of the differently fertilized plats from 1935 to 1938 are given in Table III. From these data it may be seen that in all years the plats receiving potash in conjunction with nitrogen gave significantly higher yields than those receiving potash without nitrogen or nitrogen without potash. It was also of interest to note that the  $\frac{1}{2}$ NPK plats yielded as well as either the NPK or the NK plats. Extreme annual fluctuations in yield again may be noted.

TABLE III—ANNUAL YIELD OF COFFEE FROM THE DIFFERENTLY FERTILIZED PLATS AT THE TAKASHIBA FARM

Treatment	1935-1936 (Cwt/Acre)	1936-1937 (Cwt/Acre)	1937-1938 (Cwt/Acre)
$\frac{1}{2}$ NPK.....	126	248	85
NPK.....	132	242	84
NK.....	139	249	77
PK.....	103	168	50
NP.....	97	130	16
Standard errors.....	6	18	15

#### CHEMICAL COMPOSITION OF COFFEE TREES

During October, 1937, samples of various parts of the coffee trees were taken from the check and NPK plats of the Fukuda experiment. All samples were divided into two parts, one to be dried at 70 degrees C and the other preserved in 80 per cent alcohol. The oven-dried samples were used for the total potash and phosphorus determinations while the alcohol-preserved samples were used for determining nitrates, alcohol-soluble nitrogen, protein nitrogen, sugars, starch, and acid-hydrolyzable material. The inorganic constituents (*i.e.*, nitrate, potash, and phosphorus) are given in Table IV. These data show nitrates to be present in rather abundant quantities throughout the trees; with the possible exception of the new growth, nitrogen fertilization did not affect the nitrate contents of the tree parts. All parts of the potash-fertilized trees had higher percentages of potash. Trees receiving phosphorus fertilizers had slightly higher phosphorus contents.

TABLE IV—INORGANIC CONSTITUENTS OF DIFFERENT PARTS OF FERTILIZED AND UNFERTILIZED COFFEE TREES GROWN AT THE FUKUDA FARM  
(EXPRESSED ON THE DRY BASIS)

	Nitrate Nitrogen		Total Potash		Total Phosphorus	
	Check (Per Cent)	NPK (Per Cent)	Check (Per Cent)	NPK (Per Cent)	Check (Per Cent)	NPK (Per Cent)
Roots.....	0.083	0.094	0.08	1.00	0.054	0.074
Bark of verticals.....	.085	.085	.87	1.23	.058	.054
Fruiting laterals.....	.058	.042	.59	1.14	.039	.074
New laterals.....	.126	.174	1.01	2.04	.118	.125
Leaves.....	.041	.049	.46	2.00	.088	.094
Fruit.....	.069	.079	1.29	1.75	.125	.124



In Table V are given the percentages of organic constituents found in the fertilized and unfertilized trees. There appears to be no consistent difference between the two sets of trees in percentages of alcohol-soluble and protein nitrogen. In all parts of the fertilized trees there was less total sugar than in the unfertilized trees. The new growth (lateral and leaf) of the fertilized trees had distinctly higher starch contents than the unfertilized trees. The fertilizer treatment had apparently little effect on the percentage of acid-hydrolyzable material in the trees.

TABLE V—ORGANIC CONSTITUENTS OF THE DIFFERENT PARTS OF FERTILIZED AND UNFERTILIZED COFFEE TREES GROWN ON THE FUKUDA FARM  
(EXPRESSED ON THE DRY BASIS)

	Nitrogen Fractions				Carbohydrate Fractions					
	Alcohol-Soluble Nitrogen		Protein Nitrogen		Total Sugar		Starch		Acid-hydrolyzable Material	
	Check (Per Cent)	NPK (Per Cent)	Check (Per Cent)	NPK (Per Cent)	Check (Per Cent)	NPK (Per Cent)	Check (Per Cent)	NPK (Per Cent)	Check (Per Cent)	NPK (Per Cent)
Roots	0.11	0.23	1.15	1.33	2.45	1.49	3.14	3.17	16.9	15.4
Bark of verticals	.12	.22	1.38	1.30	3.97	2.28	2.18	1.70	18.1	16.0
Fruiting laterals	.13	.17	1.70	1.73	3.20	1.97	1.87	2.02	21.0	21.1
New laterals	.31	.34	1.03	1.80	3.82	3.70	2.21	8.16	14.4	19.7
Leaves	.60	.53	1.91	1.69	6.09	5.63	8.17	13.56	9.9	9.5
Fruit	.79	.63	1.18	1.14	6.36	5.42	2.14	2.92	18.0	17.6

Since the yield and growth records show the fertilized trees to be considerably larger than the check trees, the percentages of constituents, given above, bear little relation to the total amounts contained in the trees. Potash, being the dominant limiting factor, disturbs the carbohydrate balance, as evidenced by greater starch contents of the new growth of the fertilized trees. Apparently, the growth and fruiting responses of the unfertilized trees are in equilibrium with the limited supply of potash available. The nitrogen balance is apparently undisturbed by potash deficiency.

#### SOIL CONTENTS

The coffee soils in the Kona District are, in general, derived from thin layers of volcanic ash overlying geologically recent lava flows. The soils generally do not exceed 18 inches in depth. Their organic-matter content ranges from 8 to 15 per cent, with total nitrogen content up to 1 per cent. The base exchange capacity of these soils has been found to be as high as 60 milli-equivalents per 100 grams of soil. The soils are usually slightly acid.

*Nitrogen Equilibria:*—At the Fukuda experiment the nitrate and ammonia contents of soil samples, taken at approximately monthly

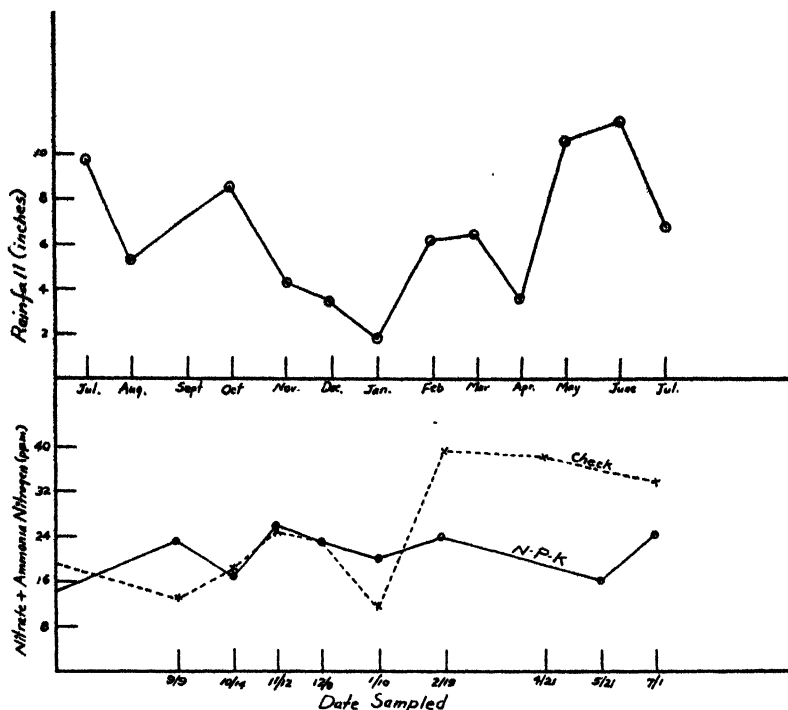


FIG. 2. Seasonal fluctuations in rainfall and sum of soil nitrates and ammonia in check and NPK plots of the Fukuda experiment.

intervals from under the trees of the check and NPK plats, were followed for a period of a year. Fig. 2 shows the changes in the combined nitrate and ammonia contents of the soils in relation to the rainfall. In the NPK plats there appears to be little variation in the total nitrate and ammonia contents of the soil throughout the year. Even the effect of the fertilizer applications were not detectable a month later. In the check plats there appeared to be a tendency for the nitrate and ammonia contents to decrease during the dry winter and increase during the wet spring. It is possible that the greater root, branch and fruit development of the NPK trees caused greater uptake of available nitrogen, thus preventing a spring accumulation in the soil.

*Available Constituents:*—In order to have some measure of the effect of fertilizer applications upon the composition of the coffee soils, the different plats of the two fertilizer experiments were sampled and analyzed. The samples were taken from the zones under the trees where fertilizers had been applied. The available phosphorus, potash, calcium, and magnesium were determined with the Truog-Hellige test kit, the pH with a glass electrode, and the available nitrogen by incubation under optimum conditions. The results of the analyses are given in Table VI.

An interesting point brought out by these analyses is that the nitrogen-fertilized Fukuda plats have become distinctly acid, resulting from a loss of both calcium and magnesium, although the calcium was not as noticeably depleted from the plats receiving superphosphate. These data would indicate the advisability of using neutral fertilizer mixtures if the practice of applying fertilizers in a localized zone is to be continued. The amounts of available potash in the soils are at a noticeably low level even in the plats receiving potash fertilizers.

TABLE VI—ANALYSIS OF SOILS FROM THE DIFFERENT PLATS OF THE FERTILIZER EXPERIMENTS AT THE FUKUDA AND TAKASHIBA FARMS

Treatment	pH	Available Nitrogen (Mg/100 Gm)	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	CaO	MgO
<i>Fukuda Experiment</i>						
Check . . . . .	5.7	13	50	75	7500	3800
N . . . . .	4.6	10	50	75	1200	600
NP . . . . .	4.5	8	150	75	3000	500
NK . . . . .	4.3	16	25	150	1000	450
NPK . . . . .	4.7	8	150	150	7000	700
<i>Takashiba Experiment</i>						
NP . . . . .	5.4	—	400	75	6500	1200
PK . . . . .	5.7	24	400	150	7500	2500
NK . . . . .	5.7	25	200	75	7000	2000
NPK . . . . .	5.3	26	370	75	7000	2000
½NPK . . . . .	5.7	24	250	75	7000	2000

### SUMMARY

This paper discusses some of the data obtained from two fertilizer experiments with coffee trees undertaken in Kona District, Hawaii, consideration being given to (a) statistical analysis of yield and growth responses, (b) chemical composition of coffee trees, (c) chemical analysis of coffee soils; and may be summarized as follows:

In both experiments potash used in conjunction with nitrogen gave increased yields over nitrogen used alone or with phosphate. In one experiment semi-annual applications of potash used in conjunction with only 40 pounds of nitrogen produced as good yields as semi-annual applications of potash in conjunction with 80 pounds of nitrogen. No responses were obtained from the use of phosphatic fertilizers. Potash, used in conjunction with nitrogen, caused increased squared circumferences of verticals and increased annual lateral growth. Nitrates were found distributed throughout coffee trees. Potash-fertilized coffee trees contained higher percentages of potash in all tree parts, and the new growth contained higher percentages of starch. Although nitrogen equilibria in completely fertilized coffee soils were constant throughout the year, some response to season and rainfall was noted in the check plats. Localized applications around the trunks of coffee trees of nitrogen fertilizers containing half ammonium sulphate and half sodium nitrate resulted in a marked increase of soil acidity after 7 years.

## ACKNOWLEDGMENTS

The fertilizer experiments discussed in this paper were designed and installed by J. C. Ripperton, agronomist of the Hawaii Agricultural Experiment Station, to whom great credit is due for his foresight. The authors are indebted to Robert Pahau, superintendent of the Kona Branch Station, for the yield records and maintenance of the coffee experiments, and to Ruth K. Yoshida and Edward T. Fukuanga, assistants in chemistry, for the chemical analyses.

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## Some Results and Suggestions Regarding the Use of Calcium Cyanamid on Apples<sup>1</sup>

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Morgantown, W. Va.*

THE experimental work on which this paper is based is in progress in an orchard situated near Martinsburg, Berkeley County, West Virginia, in the northern end of the Shenandoah Valley. The orchard extends in unequal portions northwest and southeast over the broad, relatively flat top and onto the flanks of a wide-based, low spur of Apple Pie Ridge. The crest line of this spur slopes gently southwestward. The major slopes in the orchard are not greater than 3 per cent and in most of the experimental area they rarely exceed 1 per cent. The elevation above sea level is between 620 and 640 feet. Three-quarters of a mile to the northwest, North Mountain rises abruptly to a height of 1,600 feet, furnishing considerable protection against winds from the west and north.

The block of trees utilized in this particular experiment lies wholly on the southeastern slope of the ridge and runs the full northeast-southwest dimension of the 18-acre orchard. The topography of this block, then, shows a gentle slope to the southeast.

The soil is a Frankstown silt loam which was formed by the weathering in place of highly siliceous limestone, calcareous shales, and fine-grained sandstone. This type, together with the gravelly silt loam of the same series, into which it grades imperceptibly, is used extensively for apple orcharding. The Frankstown soils are closely associated with the Hagerstown and Frederick series, which are also of limestone origin. The majority of the more profitable apple orchards in the eastern panhandle of West Virginia are situated on soils belonging to one or more of these three series.

The soil drainage, both surface and internal, is excellent. The pH of the surface 6 inches of the soil varied a few tenths about a mean of 5.4 in 1936 when the fertilizer experiment was begun. In samples taken at the same time, the organic matter content ranged from 1.8 to 2.7 per cent about a mean of 2.11 per cent as determined by Walkley and Black's rapid-combustion method. For this soil series an organic content of about 1.5 per cent is rated as low and one of the order of 2.0 per cent is considered to be medium. As in most other orchards on these limestone soils in West Virginia, available potash was a low-medium and available phosphorus very low according to the Hellige-Truog quick test. All of these data were obtained from 20 randomized soil samples taken from the experimental block. The depth of rooting in one spot in this orchard, as determined by L. P. Batjer,<sup>2</sup> was 8 feet to bedrock; this, of course, probably varies considerably from one position to another. No rock outcrops or stones are present in the orchard.

<sup>1</sup>Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 211.

<sup>2</sup>Unpublished data.

The soil is remarkably uniform through the experimental block. This is reflected by the unusual uniformity of the trees.

Before the setting of the orchard, the site had been used by the same family for more than 100 years for the production of general farm crops. No lime has been applied to this soil, and stable manure is said to have been the only fertilizer used. It is apparent that the amount of the latter has been inadequate to maintain a reasonable degree of tree vigor. For several years after the orchard was set until the increasing size of the trees made the practice less profitable, field corn was grown in successive years as an intercrop. During this period of intensive annual clean cultivation and until a volunteer bluegrass and weed sod became established when inter-cropping ceased, some soil was lost chiefly by sheet erosion.

The York Imperial apple trees set 34 x 36 were planted in 1911 so that they were 25 years old in 1936 when the experiment was initiated. The treatments given the trees were four in number and consisted of Chilean nitrate of soda, urea, sulphate of ammonia, and Cyanamid. This paper, however, concerns only those trees receiving nitrate of soda and Cyanamid. Twenty trees have received each nitrogen carrier. To select these, a section of 109 York trees in good condition were divided into three classes on the basis of similar trunk circumferences. These three classes in turn were redivided into lots of four trees more closely sized than before and the four sources of nitrogen to be given these trees were randomized in each lot subject to the restriction that no two trees closer than the diagonals should receive the same fertilizer treatment. That trees of uniform trunk circumferences were selected was attested by the fact that the 20 trees receiving nitrate of soda possessed an average trunk circumference of 887 mm, while those to which Cyanamid was applied averaged 880 mm. No yield records exist of this block as a whole or of the individual trees taken before this project began.

The basal application was 7 pounds of nitrate of soda or its equivalent in one of the three other nitrogen carriers. As no guard trees were included in the experimental layout, it was considered necessary to restrict sharply the areas covered by the fertilizer about each tree. The materials, therefore, were not applied over the entire theoretical square occupied by each tree but rather were limited to the area circumscribed roughly by the spread of the branches. This has been effective in restricting cross-feeding as is evidenced by the relatively poor performance of a dozen or so trees scattered through the block which have received no fertilizer themselves and which are not a part of the experiment.

In 1936, the first year, all fertilizers were applied on April 1, and in 1937, all were spread on March 26, 5 weeks before blossoming. In 1938, the Cyanamid only was applied in February when the frost was out of the ground at an unusually early date; the other three fertilizers were added during the latter part of March.

Beginning with 1936, only two sprays per year have been applied. These have been lime-sulphur 1-40 in the pink and petal fall plus 6 pounds of slaked lime and 3 pounds of lead arsenate per 100 gallons.

The purpose of these sprays has been chiefly protection against apple scab. All spraying has been discontinued after the petal fall.

The thin volunteer ground cover of grass and weeds was removed in the late winter of 1936, sometime before any fertilizers were applied, from directly under the spread of the branches of all the trees in the block.<sup>3</sup> The roughly-circular cleared area averaged 9.7 feet in radius for all the trees. The removal of the ground cover was done entirely by hand implements and no more deeply than necessary to eliminate the grass. In 1937, the grass and weeds appearing in the circles were merely mowed by hand.

Routine observations made during the summer of 1937 showed that the foliage of the trees receiving Cyanamid was but little superior in green color to that of the unfertilized trees. When autumn freezes killed the leaves, the check trees which were showing severe nitrogen-deficiency symptoms lost more leaves considerably sooner than those receiving the Cyanamid, but with the other three nitrogen carriers, the foliage persisted noticeably longer than that of the first two groups. In early October, 1937, following a hot, dry period of the summer, it was observed that the trees receiving Cyanamid were showing foliage injury. This consisted of a browning of the tips and margins of many of the leaves, followed by their yellowing. Partial defoliation of the trees resulted. This phenomenon was evident not only in the York Imperial trees of this fertilizer block but in adjoining blocks of Arkansas (Black Twig), Ben Davis, and Stayman Winesap, in which, although it was not a part of this fertilizer experiment, part of the trees had received the same amount of Cyanamid per tree and the remainder nitrate of soda. The York trees in the fertilizer block to which urea, sulphate of ammonia, nitrate of soda, or no fertilizer had been applied exhibited absolutely no trace of foliage injury. Apparently Cyanamid injury to the foliage of apple trees growing on a silt-loam soil is not common, although it has been reported by Hofmann (3) on a somewhat similar but very shallow silt-loam soil in Virginia. In that instance, however, the tree roots were restricted to a depth of seldom more than 2 feet, and very large quantities of Cyanamid were applied to limited areas of ground.

The question arose as to what effect the Cyanamid injury as evidenced by the leaves might have on the fruit set of the following year. At blossom time in the spring of 1938, from 500 to 900 blossom clusters were counted on the 14 Cyanamid trees and the 15 nitrate of soda trees which bloomed sufficiently heavily to make possible the selection of limbs closely comparable as to the amount of bloom, relative position on the tree, and exposure to light. After the "June drop" counts were made of the number of these same clusters which set fruit. While an average of 30.4 per cent of all those on the Cyanamid trees and 32.0 per cent of all the clusters on the nitrate of soda trees set fruit, the variation between individual trees of each of the two treatments was so great that no statistical significance can be attached to the figures.

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<sup>3</sup>This is a requirement of a second project, the biological and mechanical control of the codling moth, which utilizes the entire orchard, including the fertilizer block.

Comparative root-weight studies were made in July 1938 by the soil-tube method used previously by Batjer and Suds (1). The total weights of the roots 2 mm in diameter and less and of those 7 mm in diameter and less averaged slightly greater for the trees receiving nitrate of soda, but Student's odds for the significance of the difference were only 2:1 and 3:1, respectively, as the variability was considerable between trees receiving the same treatment.

The average cumulative trunk circumference increments for 1936 and 1937 were  $45 \pm 1.84$  mm for the nitrate trees and  $38 \pm 1.46$  mm for the Cyanamid trees. Student's odds for the significance of the difference were 34:1. When the 1938 increments are added to those of 1936 plus 1937, the average became  $54 \pm 1.83$  mm and  $43 \pm 2.74$  mm with the odds of 55:1 for the significance of the difference.

The average cumulative yields for 1936 and 1937 were  $28.5 \pm 1.19$  bushels for the nitrate of soda trees and  $26.2 \pm 0.81$  bushels for the Cyanamid trees. The odds for the significance of the difference were 5:1. The total average yields per tree for the 3-year period, 1936 to 1938, inclusive, were  $48.7 \pm 2.59$  bushels and  $39.9 \pm 1.53$  bushels, respectively, with odds of 34:1 for the significance of the difference. 1936 and 1938 were "on" years for the York Imperial trees in this orchard.

#### CONDITIONS RESPONSIBLE FOR FOLIAGE INJURY

According to literature issued by the American Cyanamid Company and to recommendations from certain agricultural experiment stations, as for example, New Hampshire (4), 400 pounds per acre is the maximum safe amount of Cyanamid to use on such a soil type. This is roughly equivalent to 1 pound per 100 square feet of soil. At the distance,  $34 \times 36$ , at which these trees were set, there are 35.6 trees per acre to each of which  $5\frac{1}{4}$  pounds of Cyanamid are applied annually or at the rate of about 187 pounds per acre, a figure well below the maximum recommended for heavier soils. However, when it is considered that this moderate amount per acre was spread on 35.6 circles of 9.7 feet in radius out of an entire acre of orchard, the rate of application becomes in effect nearly 750 pounds per acre so far as these circles are concerned, or nearly twice the maximum amount recommended per unit of area.

A second contributing cause of the injury was undoubtedly the relatively dry weather from February 23, 1937, until April 26 of the same year. On the latter date 3.52 inches of rain fell. Between these dates, only light showers fell with a maximum of 0.37 inches at any one time. The Cyanamid which was applied on March 26 in 1937 was undoubtedly changed chemically while lying on the soil surface. The possible chemical changes involved and their injurious effects have been discussed by others.

#### CONCLUSIONS AND SUGGESTIONS

Several inferences may be drawn thus far from this experiment. One which lacks originality is that Cyanamid is a nitrogenous fertilizer that cannot be used without due respect for its considerable poten-



tialities for injury. A second inference is that when typical Cyanamid injury is observed on apple foliage, the effect on the cropping of the succeeding year may not necessarily be as inconsequential as Hewetson (2) found it to be in Michigan with fruits other than the apple. This seems to be indicated by the proportionately decreased yields in the Cyanamid treatment from 1937 to 1938. Even where little or no foliage injury is apparent, it still is conceivable that there are present in the tree some unfavorable physiological effects or a physiological preconditioning which may influence the behavior of the tree at some later time. A third possibility is that a relatively heavy deep soil containing a moderate amount of organic matter does not eliminate all danger from Cyanamid in the Cumberland-Shenandoah region.

An item of particular interest to the experimenter is the indication that the technique of ring fertilizing single-tree or larger plots may be a questionable practice where Cyanamid is to be used. The temporary caustic effect of Cyanamid on the grass, where present, to which Smith and Murneek (6) ascribed the good results they obtained from spring applications of this nitrogen carrier, is not regarded in the same favorable light by the writers, who raise this question: where is the line which separates the beneficial grass injury from undesirable damage, visible or invisible, to the tree? It is admitted that spring may not be the most desirable time to apply Cyanamid, and if such is the case, this imposes another distinct limitation upon the use of this carrier of nitrogen for experimental or practical applications. Since the application of fertilizers under the spread of the branches, or just beyond, was a standard orchard practice in all but 8 out of 35 states, which replied to a recent questionnaire sent out by Schrader (5), the implication is clear that the recommendations should be changed insofar as they concern Cyanamid, for the reasons given in this report. At least some of these conditions favoring Cyanamid injury are very common occurrences in commercial orchards.

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## Phosphorus and Potassium as Supplements to Nitrogen in Sod Mulch Orchards in New Hampshire<sup>1</sup>

By G. F. POTTER and E. G. FISHER, *New Hampshire Agricultural Experiment Station, Durham, N. H.*

**I**N 1930 field plots were established in three apple orchards in southern New Hampshire to determine whether the complete fertilizer being sold for orchard use in this territory would give measurably better growth and yield than materials carrying nitrogen only. The object of the experiment was to give a direct answer to the immediate practical problem of the fruit grower. The results are here placed on record for what they are worth.

One trial, in the Batchelder orchard of mature Baldwin trees, was under conditions typical of the rather extensive Wilton area in Hillsborough County.

A second series of plots was in the White orchard near Pittsfield, about 10 years of age at the beginning of the experiment, and considered representative of the Merrimac County district. Both of these orchards were under sod mulch culture.

The third comparison was made in a cultivated block of McIntosh trees, 11 years old in 1930, and situated on the Horticultural Farm of the University of New Hampshire. All of these orchards had been fertilized since planting with nitrogen only. Hence it might be assumed that if phosphorus and potassium were actually necessary in these soils, a quick response could be expected.

The University orchard is on a soil classified some years ago as Gloucester stony, sandy loam. In a soil survey now in progress the Gloucester soil series is being broken down into several types and it is impossible to know what designation will be given this phase, nor is it possible at this time to name the soil series on which the White and Batchelder orchards are located. These are somewhat similar to, but slightly heavier than that in the University orchard.

In the White and Batchelder orchards the trees receiving complete fertilizer were arranged in three blocks of four trees each. For each individual tree in these plots a control of approximately the same size and similar in all other respects was selected near at hand, but separated from the complete plot by at least one guard row. In the University orchard, the McIntosh trees were fillers planted alternately with Northern Spy. Each one being isolated, the single tree could be made the unit in this experiment. Twenty-five pairs were selected, one tree fertilized with complete fertilizer and the other with nitrogen only. In this case records of previous production were available and the experiment was so arranged that the total production by the trees to receive complete fertilizer had been the same as that for the group to be fertilized with nitrogen only. As Snedecor (3) has since pointed out, this method of "balancing" the lots tends to increase the experimental error somewhat and is no longer to be recommended.

<sup>1</sup>Scientific Contribution No. 69, New Hampshire Agricultural Experiment Station.

The complete fertilizer used was of the "Merrimac" brand, containing 7 per cent nitrogen, 8 per cent phosphoric acid and 5 per cent potash. The nitrogen carrier used was that which for the season and locality was most economical, nitrate of soda, sulphate of ammonia calnitro and cyanamid all being used at one time or another. The quantity, materials used, and time of application are shown in Table I.

TABLE I—SCHEDULE OF APPLICATIONS ON NITROGEN PLOTS\*

Year	McIntosh University of New Hampshire		McIntosh White Orchard		Baldwin Batchelder Orchard	
	Pounds per Tree	Material	Pounds per Tree	Material	Pounds per Tree	Material
1930	3	Mixture†	3¾	Sodium nitrate	7	Mixture†
1931	3½	Mixture†	4	Sodium nitrate	7	Mixture†
1932	3½	Mixture†	4½	Ammonium sulfate	10	Mixture†
1933	4	Calnitro	4½	Ammonium sulfate	8	Sodium nitrate
1934	5	Calnitro	4¾	Calnitro	8	Sodium nitrate
1935	4	Cyanamid	5	Cyanamid		
1936	4	Cyanamid	5½	Cyanamid		
1937	4	Cyanamid	5½	Cyanamid		
1938			5¾	Cyanamid		

\*In each case the corresponding complete plot received that amount of Merrimac 7-8-5 complete fruit fertilizer which contained the same weight of actual nitrogen

†A mixture of 2½ ammonium sulfate and 1½ sodium nitrate, 18.7 per cent N

It has not been possible to make adequate tests to determine the extent to which the phosphorus and potassium penetrated the soil in the tree root zones and were taken up by the trees. Evidence from other experiments, Percival and Potter (1), indicates that the potassium would be rather readily absorbed, and this is confirmed by one test made on petioles of the leaves in the plots at the University. As to phosphorus, these soils all have a high fixing power. In a plot immediately adjacent to the McIntosh orchard used on the University Farm, 16 per cent phosphorus was applied on a sod mulch for 18 years at the rate of 400 pounds per acre, yet 2 inches beneath the surface, available phosphorus remained the same as in untreated soils.

Fairly complete records of growth and yield were taken. The annual shoot growth was estimated by measuring 24 twigs at random from each tree each year. Records of the trunk girth were also taken. In mid-summer of each season, 500 to 1,000 spurs, taken at random from top to bottom on four sides of each tree, have been classified according to whether they (a) blossomed and set fruit, (b) blossomed and failed to set fruit, or (c) did not blossom at all. From these data the percentage of spurs blossoming and the percentage set have been computed. At harvest time the total yield was recorded and a random sample of 100 apples from each tree was weighed and counted to determine the average size. In addition, this sample was sorted into four groups, depending on the percentage of the surface covered with a typical shade of red. From these data a rough estimate was made of the percentage of color. Owing to winter injury the experiment in the Baldwin orchard had to be discontinued after the winter of 1933-34. The results are summarized in Table II.

TABLE II—RESULTS FROM COMPLETE FERTILIZER AND FROM NITROGEN ONLY IN NEW HAMPSHIRE APPLE ORCHARDS

CRITERION	White Orchard McIntosh 1931 to 1938			University of New Hampshire Orchard McIntosh 1931 to 1937			Batchelder Orchard Baldwin 1930 to 1933		
	Com- plete	Nitro- gen Only	Differ- ence	Com- plete	Nitro- gen Only	Differ- ence	Com- plete	Nitro- gen Only	Differ- ence
Average yield per tree per year (pounds)	197	208	-11	312	324	-12	158	211	-53
Average weight each apple (ounces)	3.9	3.9	0	4.4	4.5	-0.1	4.0	4.2	-0.2
Per cent of surface colored red	70	66	+4	59	60	-1	70	60	+10
Per cent of spurs blossoming	64	61	+3	53	52	+1	16	24	-8
Per cent of blossoming spurs to set fruit	29	35	-6	54	53	+1	58	60	-2
Average annual twig growth (inches)	6.2	6.8	-0.6	9.9	9.7	+0.2			
Total increase in girth (inches)	9.1	8.4	+0.7	10.7	11.5	-0.8	0.6	0.3	+0.3

These results emphasize the difficulty of measuring responses to field treatments with any degree of accuracy. The plots in the White and Batchelder orchards are obviously very limited. Owing to the biennial bearing habit of the Baldwin variety, and the fact that data could be obtained for only 3 years, yields in the Batchelder orchard were subject to an extremely high error. The set-up of 25 pairs of treated and control trees in the University orchard was considered rather advantageous. An examination of the data by Fisher's method of analysis of variance indicates that none of the differences observed has statistical significance with the exception of that for color in the Batchelder orchard.

Nevertheless it is of some interest to note that the higher color of the fruit from the complete plot is correlated with lower yield. At about the same date, that is after the test had been in progress for three or four seasons, similar differences were observed in the White orchard. Here there were in addition lower set, and shorter shoot growth. All of these differences might be due to a lower plane of nitrogen supply. The weight of actual nitrogen was identical in the two treatments, but it is conceivable that that in the mixed fertilizer might have been less fully available to the trees.

In the White orchard growth of mulch was better where complete fertilizer was used. This no doubt resulted in better conditions for growth and production and tended to eliminate the differences observed earlier in the experiment. In the cultivated orchard at the University no difference in cover crop was noted at any time, nor was there any noticeable difference in the yield of mulch in the Batchelder orchard.

These results are at variance with those obtained in other sections, and even in Massachusetts, Shaw (2). But in these three orchards there certainly seems to be no response to the complete fertilizer which at present would justify the commercial fruit grower in this area in making the extra investment necessary for purchase of this material.

The writers are indebted to H. A. Rollins, who arranged the plots in the White and Batchelder orchards.

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# A Preliminary Report on a Study of the Nutrient Level of Orchard Soils in the Eastern Panhandle of West Virginia and its Relation to Tree Condition and Productivity<sup>1</sup>

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Morgantown, W. Va.*

THIS study of the nutrient level of orchard soils is part of an extensive program which has as its aim a better understanding of the natural phenomena associated with orcharding under West Virginia conditions. In order to understand more fully the variations in orchard behavior on different soils, a knowledge of the several nutritional factors in the soil should prove of fundamental importance.

To obtain such information, soil samples were obtained from representative apple orchards in the eastern panhandle of the state. In September 1937, 38 orchards in Jefferson county, and in August 1938, 33 orchards in Berkeley county, were sampled. Samples were taken with a California soil-tube to a depth of 24 inches. Each core of soil was separated into three approximately 8-inch sections, from 0 to 8 inches, 8 to 16 inches, and 16 to 24 inches. A single composite sample for each of the three depths was obtained from each orchard, except from those in which more than one soil series was encountered, in the event of which a composite sample for each soil series was obtained. For any given soil series, sampling stations were selected at random so that they were representative of the variations in topography and plant growth within the orchard. At any one station, four cores of soil were obtained with the soil-tube, one at each of four regularly spaced intervals around an apple tree, just under the spread of the branches. In general, for any one sample, cores were obtained at from two to eight stations. A total of 100 samples for each depth of sampling was secured from the two counties. Each sample was air-dried, thoroughly mixed, and screened through a 10-mesh sieve.

The material in this paper is a preliminary report of analyses of the 0 to 8-inch samples only. The pH, the percentage of organic matter, the exchangeable potassium, expressed as K in pounds per acre (*i. e.*, per 2,000,000 pounds of surface soil), and the available phosphorus, given as P in pounds per acre, have been determined. The pH measurements were made with a glass electrode. Organic matter was determined by the wet-combustion method of Walkley and Black. Bray's quick-test procedure, using a neutral sodium perchlorate extractant, was used to determine the exchangeable potassium. The available phosphorus was determined by the Hellige-Truog quick-test method. For West Virginia soils, both of these latter procedures have been found to be sufficiently quantitative for the survey type of study herein considered.

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<sup>1</sup>Published with the approval of the Director of the West Virginia Experiment Station as Scientific Paper No. 213.

There were 12 different soil series in the orchards sampled. Of these, the Hagerstown, Frankstown, and Frederick series are the most important and the most extensively devoted to orchards. As a group, they are relatively deep soils originating from siliceous limestones, calcareous shales, and fine-grained sandstones. The Dekalb, Lehigh, Meigs, and Berks series are shale soils, less extensively devoted to orcharding yet sufficiently so to be of considerable importance in the eastern panhandle of West Virginia. They are derived from non-calcareous shales and sandstones; the Dekalb and Berks series are yellow to yellowish-grey in color, while the Lehigh and Meigs are red, the latter being composed of a mixture of the Dekalb and Lehigh series. The other five series, in general, are not found in orchards except in small areas associated intimately with larger areas of the first seven series.

The results of the analyses are summarized in Table I. For this preliminary consideration, it seems best to report for each soil series only the total range or distribution of the values for the nutritive factors determined, together with the approximate median around which most of the values are distributed. The number of samples tested from the Dekalb, Lehigh, Meigs, and Berks series, the shale soils, is small relative to the number of samples tested from the Hagerstown, Frankstown, and Frederick series, the limestone group. However, the number of orchards on the shale soils in the two easternmost counties of the eastern panhandle is also relatively small; the total number of samples, 13, in this group includes the better orchards and the major part of the orchard acreage on shale soils in these two counties. Therefore, these samples, though small in number, can be considered typical

TABLE I—SUMMARY OF THE RESULTS OF ANALYSES OF 0 TO 8 INCH SOIL SAMPLES FROM REPRESENTATIVE ORCHARDS IN BERKELEY AND JEFFERSON COUNTIES, WEST VIRGINIA, 1937-38

Soil Series	pH		Exchangeable Potassium (Pounds per Acre)		Available Phosphorus (Pounds per Acre)		Organic Matter (Per Cent)		Number Samples Tested
	Total Range	Approximate Median	Total Range	Approximate Median	Total Range	Approximate Median	Total Range	Approximate Median	
Hagerstown	5.19-6.74	5.90	150-300	220	10-70	35	1.31-3.53	2.05	34
Frankstown	5.32-7.00	6.00	116-300	225	25-150	35	1.11-3.08	2.15	34
Frederick	5.45-6.28	5.95	180-310	220	15-70	25	1.37-2.93	1.95	14
Dekalb	4.66-5.73	5.40	180-213	180	20-25	25	1.47-2.23	1.70	5
Lehigh	4.87-5.52	5.20	176-213	195	15-20	18	1.20-1.72	1.45	2
Meigs	5.13-5.28	5.20	155-180	158	10	10	0.90-1.45	1.20	2
Berks	5.30-6.69	5.90	147-240	180	20-35	30	1.18-2.15	1.75	4
Elk	5.84	—	206	—	63	—	2.33	—	1
Decatur	6.44	—	300	—	43	—	2.21	—	1
Hollywood	7.77	—	172	—	15	—	4.80	—	1
Holston	6.66	—	174	—	35	—	1.48	—	1
Murrill	6.66	—	235	—	50	—	1.59	—	1

for orchards on shale soils in the area considered. The total of 82 samples from the limestone group is also representative of the orchard acreage on these soils. Any comparisons made in the subsequent discussion will concern the soils as groups, the limestone and the shale, rather than individual series. Because of their relative unimportance as orchard soils and the small number of samples, the Elk, Decatur,

Hollywood, Holston, and Murrill series will not be discussed; the results from these series are included in the table for any general interest they may have.

The total pH range for the limestone soils is only slightly higher than that for the shale soils. The lowest pH recorded in the limestone group, from the Hagerstown series, was 5.19, and the highest, from the Frankstown series, was 7.00. For the shale soils, the lowest pH, 4.66, was from the Dekalb series, and the highest, 6.69, was from the Berks. However, the approximate medians of the limestone soils are from 0.5 to 0.7 of one pH above those of the shale group, with the exception of the Berks series, indicating that a lower pH may be expected among the shale soils.

The total range in values for exchangeable potassium is much greater for the limestone soils than for the shales. The lower level is about the same for both classes of soil series, except for the Frankstown series, in which the analysis of one sample was 116 pounds of exchangeable potassium per acre. However, the next higher analysis above this low value in the Frankstown series was 180 pounds per acre. The upper limits of the range for the limestone group are considerably above those of the shale series. The approximate medians for K for the limestone series are higher than the medians of the shale group; indeed, those of the limestone soils are slightly above the upper limits of the total range for the shale group.

The results from the phosphorus determinations show a similar trend toward a higher available phosphorus level in the limestone group. The limestone series show a wider range of values, and the approximate medians for these soils are higher than those for the shale group.

The amount of organic matter in the limestone soils tends to be slightly higher than in the shale group, although the difference as indicated by the median values is no more than 0.7 per cent. In general, an organic matter content of 1.5 per cent may be considered as low, 2.3 per cent as medium, and above 3.0 per cent as high. The results indicate that the shale soils may be expected to average toward the lower level, while the limestone soils fall in the medium class.

In general, the performance of apple trees in orchards on the two soil groups is sharply contrasted. The condition of trees on the limestone soils is superior to that of trees on the shale group. Trees on soils of the shale series tend to be smaller and less vigorous than comparable trees on the limestone soils. The few yield records available indicate a higher productivity for orchards on the limestone-derived soils. The soils of the shale group are extremely shallow; in many instances, shale or even bedrock is encountered within 12 to 18 inches of the surface with the result that tree roots ramify through a very shallow profile. On the other hand, the limestone soils are deeper, except in areas subject to severe geological erosion or in the zone of limestone outcrops; apple tree roots have been found in some places at a depth of 8 feet. In ordinarily dry years orchards on the shale soils suffer acutely from the lack of moisture, a deficiency the result partly of the shallow rooting area and partly of the inherent inability of the shale soils to



hold sufficient available moisture. This, together with the combination of the limited depth of rooting and the tendency toward a low nutrient level, probably accounts for much of the poor performance of orchards on the shale soils.

The general inferiority of the soils of the shale group is also reflected in the orchard cover, whether it is a sod or a volunteer or seeded cover crop. The limestone soils support, in general, a heavier, more uniform cover despite the fact that the more vigorous condition of the trees increases the amount of shade in the orchard.

The differences in the several nutrient factors between the limestone group and the shale group are not sufficient to warrant a definite association of any of the factors with tree condition or productivity or with the performance of the orchard cover. It suffices to point out that, in general, the shale soils when compared with the limestone group tend to have a lower level of the several soil factors studied and, at the same time, support an inferior cover and stand of trees. Although this lower level of the soil factors may contribute to the poor performance of trees and cover on the shale soils, the results indicate that some other factor or factors, such as moisture relationships, which as yet have not been fully investigated, are limiting and need to be studied before a complete or more satisfactory explanation of the differences in plant growth on the two soil groups can be reached.

#### ACKNOWLEDGMENT

The author thanks R. S. Marsh of the Department of Horticulture, West Virginia University, for his suggestions and criticisms, and the Department of Agronomy and Genetics for the use of facilities in the soils laboratory. He acknowledges the interest of the American Potash Institute in providing a fellowship for carrying out this work.

## Nitrate Movement in Orchard Soils in Relation to Time of Application<sup>1</sup>

By L. P. BATJER and J. R. MAGNESS, *U. S. Horticultural Station, Beltsville, Md.*

**N**ITRATE of soda at a rate to give approximately 40 parts per million in the top foot of soil was applied to mature Delicious apple trees growing in a Berks shale with a field capacity for water of about 25 per cent, and to York Imperial trees in a Hagerstown clay with a field capacity of approximately 30 per cent. Sod was removed from the area of application prior to treatment. An application was made to one of the several plots on each of the following dates: October 15, 1937, November 21, 1937, April 5, 1938, May 5, 1938, and July 27, 1938. Other trees received no fertilizer. Five trees of each variety in a modified Latin square were used for each treatment. Sampling of trees for nitrogen intake and of soil for nitrate content was on an individual tree basis.

Soil under check trees receiving no fertilizer contained not more than 1 to 2 parts per million nitrate at any sampling date.

Results of nitrate movement in the soil were very similar for the two orchards. Eight inches of rain coming within a month after the October application was sufficient to carry most of the nitrate from the top foot of soil where root concentration was highest. There was little fixation of nitrate during the winter as practically the total amount applied in October or November was recoverable in April.

The rate of fixation or absorption by roots in the second foot or below during the summer was relatively slow. More than half the nitrate found in this zone in April was still recoverable in September.

Little nitrate from spring or summer applications was found below the first foot, although the rainfall averaged 3 inches per month during the summer. Removal of water by evaporation and transpiration was apparently sufficient to equal the rainfall and to prevent downward movement of nitrates. Absorption by the trees and fixation of nitrates in the top foot of soil occurred rapidly in the summer months. Generally less than one-quarter of that applied in the spring or summer could be recovered 4 months later.

No significant increase in nitrogen content of roots and twigs occurred before the following March in the York Imperial trees (Orchard No. 1) receiving fall applications. In the Delicious trees on shale soil (Orchard No. 2), marked increase in nitrogen content of roots occurred during the dormant season, the greatest increase occurring where large quantities of nitrate were present in the top foot of soil (application of November 23).

In these moderately heavy soils requiring 4 to 5 acre inches of water per foot of depth for saturation, downward movement of nitrates was

<sup>1</sup>A preliminary summary of work which is being continued and which will be published in full at a later date.

sufficiently rapid to indicate that if as much as 15 inches of precipitation occurred during the dormant season following a fall application much of the nitrate would be below the depth of effective root concentration at the time growth started in the spring.

## The Nitrogen Requirement of the Apple

By J. R. MAGNESS and L. O. REGEIMBAL, *U. S. Horticultural Station, Beltsville, Md.*

SINCE nitrogen is the first limiting element for growth and productivity in most American apple orchards, a knowledge of the quantity that must be taken into the full bearing tree each year to maintain production is basic to the nitrogen fertilizer program. The literature of American horticulture is full of references giving recommendations on the quantity of nitrogenous fertilizer to apply under varying conditions, but there are relatively few references on the amount of nitrogen the tree actually requires. Van Slyke, Taylor, and Andrews (6) as early as 1905 estimated the total quantity of nitrogen for heavy bearing Baldwin trees as 1.413 pounds per year, and for Rhode Island Greening trees at 1.527 pounds per year. More recently, Heinicke (3) has estimated the nitrogen requirements for a large apple tree producing 25 bushels of fruit as 3.9 pounds per year. Many analyses have been reported on the nitrogen content of fruit, leaf, stem, and root tissues, but there are few references to the retransfer and reutilization of nitrogen in the trees, which must be considered in determining the nitrogen requirement.

Since considerable data have been secured recently on the nitrogen content of various tissues of the apple tree, it seems desirable to summarize them to add to the available information on the nitrogen required for growth and fruit production in apples.

*Nitrogen in the Fruit Excluding Seeds:*—The nitrogen content of fresh fruit from Delicious trees receiving fairly heavy applications of nitrate of soda was .0378 per cent  $\pm$  standard error of .0014 based on individual samples from 17 trees in 1938. Fruit from four trees which did not receive nitrogen in 1938 averaged  $.0278 \pm .0019$  per cent nitrogen. Individual samples from 15 heavily nitrated trees of York Imperial contained an average of  $.0347 \pm .0009$  per cent nitrogen, while five trees that received no nitrogen for the 1938 season but were previously well fertilized, produced fruit averaging  $.032 \pm .003$  per cent nitrogen.

These data are in line with those of Gourley and Hopkins (2), who report for Stayman Winesap fruit .0217 per cent nitrogen from non-fertilized trees in sod, and .0412 per cent nitrogen from trees receiving 12 pounds of nitrate of soda per tree. For Wealthy in cultivation they report .0285 per cent for fruit from non-fertilized trees, and .0380 per cent for trees receiving  $5\frac{1}{4}$  pounds of nitrate of soda per tree.

Thus on well fertilized trees the nitrogen content of fruit will range around 0.035 to 0.04 pounds per 100 pounds fresh weight. This nitrogen is of course lost to the tree and orchard when the fruit is removed.

*Nitrogen in the Seeds:*—Apple seeds average about 15 to the gram in weight, and most varieties average about six seeds per fruit. On this basis, a tree maturing 2,000 fruits would produce about 800 grams of seed. Murneek (5) has reported the nitrogen content of apple seeds as ranging between 5 and 6 per cent. Using these figures, the nitrogen

in the seed per tree would total between 40 and 50 grams, or approximately .1 pound.

*Nitrogen in Abscising Blossoms:*—Normally only about 5 per cent of the apple blossoms that open set fruit. A tree that matures 2,000 fruits is likely to produce up to 40,000 blossoms. Howlett (4) found that the nitrogen content of abscising blossoms would average approximately 1 milligram per blossom. Using his figures, the nitrogen loss to the tree due to blossom drop would be about 40 grams, or about .09 pound. This nitrogen does not disappear from the orchard, but does represent necessary intake into the tree.

*Nitrogen in the Leaves:*—Leaf samples taken July 28, 1938, from 15 individual Delicious trees previously well supplied with nitrate of soda, averaged on a dry basis  $2.15 \pm 0.03$  per cent nitrogen. Ten trees not fertilized for the 1938 season, averaged in the leaves  $1.90 \pm 0.076$  per cent nitrogen. Fifteen nitrated York Imperial trees on the same date averaged  $2.16 \pm 0.022$  per cent nitrogen in the leaves, and 10 non-nitrated trees averaged  $1.99 \pm 0.08$  per cent.

However, a large portion of this nitrogen moves from the leaves back into the stem tissues prior to leaf fall. Leaves which had turned yellow and were ready to fall were sampled November 2, 1938, when 50 to 80 per cent of the leaves had fallen. Leaves from similar positions on the 15 nitrated Delicious trees sampled in July, contained at leaf fall  $1.16 \pm .025$  per cent nitrogen. Similar leaves from the 15 York Imperial trees contained  $0.90 \pm 0.014$  per cent nitrogen. There was no significant difference in nitrogen content of leaves from nitrated and non-nitrated trees when the leaves fell. A little less than half the nitrogen on a dry weight basis had moved out of the Delicious and a little more than half had moved from the York Imperial leaves.

The total weight of leaves produced by a tree will of course vary with the size of the tree, the growth it is making, and the variety. Careful records taken in connection with fruit thinning experiments indicate that a 25-year-old apple tree may carry as many as 200,000 leaves, weighing around 200 pounds fresh weight, or 70 pounds dry weight in midsummer. Such a leaf system would be large for most full bearing trees under eastern orchard conditions. The dry weight of these leaves by the end of the growing season would be reduced to not more than 60 pounds, due to movement of carbohydrates and nitrogenous materials out of the leaves. Based on these estimates, the total nitrogen in the leaves in midsummer would approximate 1.50 pounds per tree, but by the time of leaf fall this would be reduced to about 0.60 pounds. This nitrogen at leaf fall represents a part of that which must be taken into the tree each year to maintain the growth conditions, but most of it may ultimately be restored to the soil when the leaves decompose.

*New Wood Growth:*—The new wood formed each year consists of extensions from all growing points and also a new layer on all trunk and branch tissue. New terminal and spur wood growth in midsummer has averaged slightly over 1 per cent nitrogen on a dry weight basis in highly nitrated trees and .6 per cent in trees low in nitrogen. Much of this nitrogen, however, can be considered as translocated from wood laid down earlier. For example, in one set of experiments 1937 wood

taken June 10, 1937, contained 1.15 and 1.37 per cent nitrogen respectively in two sets of trees. Wood from the 1936 extension on the same branches taken at the same time and consisting of 1936 growth together with the 1937 ring of growth, analyzed only .37 and .40 per cent nitrogen. Since in 1936 this tissue formed in 1936 was undoubtedly above 1 per cent in nitrogen, these data indicate a marked translocation out of the 1936 wood when 1937 growth occurred. Outer wood from 4-year-old limbs taken from the same trees on the same date analyzed .22 and .24 per cent nitrogen respectively. These trees had been well supplied with nitrogen prior to 1937, but had not received nitrogen fertilizer prior to date of sampling in 1937. Outer wood on the trunk of these 7-year-old trees was similar in nitrogen content to that on the 4-year-old limbs. Wood from the centers of the trunks of similar, but not the same, 7-year-old apple trees always well supplied with nitrogen contained .105 per cent nitrogen. These samples from relatively young trees did not show the color of typical heart wood. A few analyses of heart wood of old apple trees have shown an average of .077 per cent nitrogen ultimately trapped in old nonliving wood.

These data indicate that the wood of new shoots, consisting mainly of living cells, contains 1 per cent or above nitrogen on a dry basis, that new trunk and branch tissue, consisting largely of nonliving cells, contains .2 or .3 per cent nitrogen; and that old sap wood and heart wood contains about .1 per cent or less of nitrogen. Nitrogen apparently largely moves out of the older wood into new growth and only a small residue remains trapped in the old wood.

A rather generous estimate of the new wood laid down each year in a 20- to 25-year tree would be 80 pounds dry weight. The total nitrogen required for this growth, in addition to that translocated from older tissues, probably does not exceed .15 per cent, or 0.12 pounds per year.

*Nitrogen in Bark:*—Analyses have indicated that the bark, consisting largely of living cells, is more uniform in nitrogen content than the wood. In samples taken June 10, 1937, from the same trees used for wood studies, bark from the trunk of 7-year-old trees contained .66 per cent nitrogen; that from limbs 4 years old, .66 per cent; that from 1-year-old wood, .85 per cent; and that from the current season's growth 1.09 per cent, all on a dry weight basis. On August 12, analyses from the same trees showed .58, .63, .68, and .80 per cent for the same tissues. These trees had not received nitrogen in 1937. Trees receiving nitrate of soda in 1937 showed on August 12 in similar tissues .70, .78, 1.09, and 1.41 per cent nitrogen. Thus the bark stores nitrogen in rather large quantities. It seems safe to assume that nitrogen above .6 per cent in the 7- to 1-year-old bark of these trees is available for translocation when needed for growth.

Considering the bark on the tree as a whole, it seems probable that the total new weight laid down per year will not exceed 35 pounds green weight, or 15 pounds dry weight. On the basis of .6 per cent residual nitrogen in this bark tissue, the total quantity of nitrogen tied up in the bark each year will be approximately .09 pounds.

*Nitrogen in Roots:*—Nitrogen in small roots will vary greatly in amount, depending on the season of the year and available nitrogen in

the soil. Analyses of roots under 1 millimeter in diameter from 7-year trees in our tests have shown as high as 1.97 per cent nitrogen on a dry basis and as low as 0.82 per cent. These trees were fairly well supplied with nitrogen fertilizer. Five samples of roots  $\frac{1}{8}$  to  $\frac{1}{2}$  inch in diameter from five mature Delicious trees which had not received nitrogen fertilizer during the preceding year averaged on June 21, 1938, on a dry basis,  $0.525 \pm .051$  per cent nitrogen. Fifteen samples from 15 fertilized trees averaged  $0.904 \pm .054$  per cent nitrogen. Roots of five unfertilized York Imperial trees averaged on the same date  $0.459 \pm .068$  per cent, while 14 fertilized trees averaged  $0.523 \pm .030$ .

Analyses were made of tissues from large roots of mature Delicious and York Imperial trees receiving commercial nitrogen fertilizer applications. The samples from roots  $2\frac{1}{2}$  to 4 inches in diameter were separated into outer root, consisting of a mixture of bark and outer wood within  $\frac{1}{2}$  inch of surface, and inner wood, tissue more than  $\frac{1}{2}$  inch below the surface. There was no significant difference between the varieties. The six outer samples averaged  $0.386 \pm .042$  per cent nitrogen, and the six inner samples averaged  $0.190 \pm .033$  per cent.

These data indicate that in roots also a considerable portion of the nitrogen moves out as the tissues become older. In younger roots, nitrogen content varies widely with the available supply. These roots appear to be very important nitrogen storage organs. Considering the root system as a whole, it would appear that 0.45 per cent is a liberal figure for residual nitrogen unavailable for translocation and utilization in other parts of the tree. Chandler (1) found the dry weight of the root systems of apple trees 6 to 9 years old growing at Ithaca, New York, to equal about 70 per cent of the top, leaves and fruit excluded. The same varieties at Davis, California, in an excellent soil under irrigation, produced roots equal to only about 43 per cent of the top weight, dry basis. Thus a tree under eastern conditions producing 95 pounds dry matter in the top wood and bark might produce 60 to 70 pounds of dry matter in the roots. The residual nitrogen in 65 pounds dry root tissue at 0.45 per cent would total 0.29 pounds nitrogen.

In Table I, the estimated weight and nitrogen content of various tissues formed in full bearing apple trees under good productive conditions in the eastern states are summarized. These estimates are based on averages for productive 25-year-old trees, rather than maximums. The nitrogen contents for wood, bark, and root tissue are based on residual nitrogen, not available for retransfer and reutilization, rather than on the content in these tissues when first laid down.

The more vigorous and productive trees in western irrigated orchards would require somewhat greater nitrogen intake than these figures indicate. Average yields of 800 to 1,000 pounds of fruit per tree are not unusual in western orchards. The foliage weight may be higher than indicated in Table I, and total weight of wood, bark, and roots may be somewhat greater.

This analysis of the nitrogen requirement of full bearing apple trees indicates a necessary intake of from 1.5 to 1.75 pounds actual nitrogen per tree per year. Of this amount, almost 1 pound is permanently

TABLE I—ESTIMATED NITROGEN REQUIREMENT OF 25-YEAR-OLD APPLE TREES IN GOOD VIGOR TO MAINTAIN THEM IN THAT CONDITION

Tissue	Estimated Weight Per Year (Pounds)		Approximate Nitrogen Content (Per Cent Dry Weight)	Nitrogen Permanently Removed From Soil (Pounds)	Removed From Soil But Ultimately Returned
	Fresh	Dry			
Fruit (exclusive of seeds)	600	100	0.23	0.23	—
Seeds	—	1.8	5.50	0.10	—
Abscising blossoms	14.0	3.0	3.00	—	0.09
Leaves					
Midsummer	200	70.0	2.15	—	—
At leaf fall	—	60.0	1.00	—	0.60
Wood growth	133	80.0	0.15*	0.12	—
Bark growth	33	15.0	0.60*	0.09	—
Root growth	130	65.0	0.45*	0.30	—
Total	—	—	—	0.84	0.69

\*"Residual" nitrogen considered not available for translocation and reutilization.

removed from the orchard soil, while from 0.5 to 0.75 pounds ultimately returns to the soil with the decay of blossoms and leaves. If less than these amounts are available, it will be reflected in reduced tree growth, reduced leaf area, and reduced production. Quantities of nitrogen greatly in excess of these amounts may result in fruit high in nitrogen content and consequently of poor color.

It should be emphasized that these data apply to nitrogen intake and not to fertilizer applications. Nitrogen intake may be much greater with certain soils and cultural practices or may be much less than the amount applied to the soil in the form of nitrogenous fertilizers.

For trees very low in nitrogen, considerably greater quantities would need to be taken into the tree for 1 or 2 years to build up the storage reserves to the point found in these investigations, which are based on trees receiving ample annual applications of nitrogenous fertilizers.

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# Response of Peach Trees to Potassium and Phosphorus Fertilizers in the Sandhill Area of the Southeast

By L. E. SCOTT, *Sandhill Experiment Station, Columbia, S. C.*

**I**N the experimental use of commercial fertilizers in the peach orchard few instances have been found where definite response in tree behavior resulted from the application of phosphorus or potassium alone or in combination. Apparently most of the soils where tests have been conducted contain a sufficient supply of these elements to satisfy the tree requirements during the life of the orchard, even though in many cases other crops grown on these soils respond to phosphorus and potassium applications. However, recently Dunbar and Anthony (1) have reported instances of severe potassium deficiency in commercial orchards in Pennsylvania. Rawl and Stallworth (2) have reported the correction of an abnormal deficiency condition in peach trees grown in the Piedmont area of South Carolina by applications of a complete fertilizer and lime, while Davidson and Blake (3) recommend the regular use of complete fertilizers in peach orchards on the light Coastal Plain soils as a result of nutrient studies in sand culture accompanied with observations in the field.

This paper presents certain phases of a general experiment in peach fertilization being carried on at the Sandhill Experiment Station, Columbia, South Carolina.

The orchard is located on a coarse phase of Norfolk sand typical of the Sandhill region of the Southeast and on which are located many of the commercial peach orchards in North and South Carolina. This soil type is characteristically low in fertility and, in general, crops give marked response to nitrogen, phosphorus and potassium applications as well as to certain of the so-called minor elements.

## PLAN OF EXPERIMENT

The experimental Elberta orchard was planted on land newly cleared of the native growth of long leaf pine and scrub oak in 1929. Differential fertilizer treatments were begun the spring following planting: nitrogen, phosphorus and potassium being applied at rate of .10 pound,  $\text{NH}_3$ , .05 pound  $\text{P}_2\text{O}_5$  and .05 pound  $\text{K}_2\text{O}$  per tree the first year, increasing to .8 pound  $\text{NH}_3$ , .4 pound  $\text{P}_2\text{O}_5$  and .4 pound  $\text{K}_2\text{O}$  after the third year in the orchard, and maintained thereafter at that rate annually. Nitrogen was derived 80 per cent from nitrate of soda and 20 per cent from cottonseed meal phosphorus from acid phosphate and potassium from muriate of potash. Prior to 1935 phosphorus and potassium were applied at time of turning under the winter cover crop in the spring. Since 1935 application of these elements has been made in the fall at time of seeding of the winter cover crop. No effort has been made to effect sub-soil applications of the fertilizer other than that caused by the disking or plowing of the soil during normal orchard

cultivation. The orchard has received two 1,500 pound per acre applications of dolomitic limestone. After the trees were 3 years old all fertilizer applications were made broadcast as an all-over application between the trees. Until that time application was made under the spread of the limbs.

Plots consist of single rows eight trees long separated by buffer rows and arranged in triplicate series with check plots (complete fertilizer treatment) every five plots. Analysis of the data has been prepared on the basis of comparison with adjusted or graded check plot performance with the variance of the trees within and between check plots serving as a standard error of the experiment as suggested by Love (4). Individual tree variation within plots has been great as is usual with such orchard field experiments causing a rather high standard error and necessitating large differences for significance.

Five treatments are considered in this paper: (a) no fertilizer, (b) nitrogen only, (c) nitrogen and phosphorus (or minus potassium treatment), (d) nitrogen and potassium (or minus phosphorus treatment), (e) nitrogen + potassium + phosphorus (or complete fertilizer). These will be discussed in their effects on yield of fruit, tree growth and foliage symptoms, fruit bud development, and cover crop growth in the orchard.

#### EFFECT OF TREATMENT UPON TREE PERFORMANCE

*Fruit Yield:*—Yield of fruit must be judged the ultimate criterion of any experimental treatment in the orchard. Other effects may be highly correlated and of interest to the investigator but fruit production must be considered of primary importance. The complete fertilizer treatment has given decidedly greater yields throughout the experiment (Table I). The minus fertilizer trees have been very weak, although the tree mortality has been no higher than that of the other treatments. The minus potassium plots have been lower in production all years and very significantly so in the last four crops. In 1938 the minus potassium trees were lower in yield than the no-fertilizer plots. The quality of the no-potash fruit has been very inferior, many of the peaches failing to develop normally. The minus phosphorus plots have been slightly lower in yield throughout the experiment except in 1937 when the crop was almost a total failure from frost damage.

TABLE I—RESPONSE OF PEACH TREES TO PHOSPHORUS AND POTASSIUM APPLICATIONS IN AN ORCHARD ON NORFOLK COARSE SAND (COLUMBIA, SOUTH CAROLINA)

Treatment	Fruit Yield per Tree (Pounds)						
	1933	1934	1935	1936	1937*	1938	Average
No fertilizer . . . . .	23.0	38.8	64.4	43.9	1.3	46.6	36.3
Nitrogen . . . . .	48.6	56.8	91.8	32.4	13.6	36.6	46.8
Nitrogen-phosphorus . . . . .	67.0	68.5	111.4	69.0	11.4	31.7	61.6
Nitrogen-potassium . . . . .	70.2	83.6	163.2	74.8	54.3	123.4	96.1
Nitrogen-phosphorus-potassium . . . . .	87.6	90.1	193.7	109.6	29.5	146.4	109.5
Differences necessary for significance (Odds 19:1) . . . . .	23.5	23.6	30.4	29.4	17.0	41.6	11.6

\*1937 yields lowered by frost damage.

In discussion of the response to potassium and phosphorus, reference is made to these treatments lacking just one of the two elements in order to more definitely ascribe results obtained. The data in the yield and growth tables show the more extreme effects where both potassium and phosphorus were omitted.

*Effect in Foliage:*—There was no evidence of potash deficiency in the minus-potassium plots until after the 1934 crop had been produced. At that time the minus potassium trees showed a slight rolling and yellowing of the foliage. This became more pronounced with each succeeding crop until in the past two seasons practically all of the foliage on these trees showed extreme symptoms with the leaves about one third normal size. In severe cases a breakdown of the tissue occurs at the leaf margin. The foliage symptoms of potash deficiency usually do not appear until about time of or after harvest. For this reason an affected tree may show extreme symptoms late in the season, yet appear normal the following spring. Potash deficiency develops first at the tips of the shoots and progresses inward toward the trunk. Defoliation does not occur prematurely, rather there is a tendency for the minus potassium trees to retain the leaves unusually late due to a failure of the abscission layer to develop normally.

The minus-phosphorus trees have failed to show such extreme foliage symptoms although the leaves are a dull darker green than normal and rather leathery in texture. The leaves have been larger than those in the check trees and to casual observation the trees seem normal.

It is possible that the symptoms of potassium deficiency would have developed earlier in the test had a non-sodium source of nitrogen been used. Wallace and Cooper (5) have shown with cotton that the sodium in nitrate of soda may substitute for potassium to a marked extent in the Norfolk sand soils.

*Trunk Growth:*—The trees of the minus fertilizer and nitrogen only treatments have been much smaller in trunk growth (Table II). The omission of potassium has apparently not resulted in smaller trunk growth, both the cross-section areas and the average annual increment being slightly greater than that of the complete fertilizer treatment.

TABLE II—RESPONSE OF PEACH TREES TO PHOSPHORUS AND POTASSIUM APPLICATIONS IN AN ORCHARD ON NORFOLK COARSE SAND (COLUMBIA, SOUTH CAROLINA)

Treatment	Annual Increase in Cross-Section Area (Sq. Cm)									
	1930	1931	1932	1933	1934	1935	1936	1937	1938	Average
No fertilizer	4.94	6.04	14.73	17.54	13.82	8.62	2.94	12.87	11.10	10.29
Nitrogen	9.05	10.45	17.93	20.80	20.75	3.11	5.35	16.73	9.05	12.59
Nitrogen + phosphorus	10.08	11.64	26.67	25.69	19.40	15.51	11.61	30.31	20.22	19.01
Nitrogen + potassium	6.66	10.00	23.70	19.60	24.46	11.55	5.56	16.40	10.34	14.25
Nitrogen + phosphorus + potassium	9.52	12.38	32.44	23.37	21.50	15.23	10.10	26.39	18.20	18.80
Differences necessary for significance (Odds 19:1)	2.33	2.35	4.39	4.54	5.27	6.45	3.28	8.22	7.22	—

On the other hand the minus-phosphorus trees have been smaller in cross-section area and have had significantly less annual increment in cross-section area in 8 of the 9 years of the experiment.

*Shoot Growth:*—The differences in length of shoot growth have been somewhat inconsistent, and not pronounced in any instance. Apparently the length of shoot growth is influenced more by the seasonal moisture availability than by the fertilizer treatment. The minus-potash twigs were much more slender than twigs from the normal trees. It was also quite evident that the under nutritioned trees had noticeably fewer growing points, a fact not considered in the shoot growth measurements. In other words, although the data shows little difference in average shoot length, the total growth for each tree was unquestionably greater in the complete fertilizer plots.

*Bud Development:*—The incomplete fertilizer treatments have all shown in general fewer buds per unit length of shoot growth than the complete treatment (Table III). The differences were greatest in 1935, 1936 and 1938 and least in 1937 when the light crop resulted in heavy shoot growth. In 1938 the failure of the trees not receiving potassium to develop fruit buds was especially striking. In the same season the minus-phosphorus trees showed fewer buds than the complete fertilized trees, but were not so severely affected as the minus-potash trees. Here again the data presented fails to represent the entire picture, the total number of fruit buds per tree would undoubtedly show even greater differences between treatments.

TABLE III—RESPONSE OF PEACH TREES TO PHOSPHORUS AND POTASSIUM APPLICATIONS IN AN ORCHARD ON NORFOLK COARSE SAND (COLUMBIA, SOUTH CAROLINA)

Treatment	Number of Fruit Buds per Cm of Shoot Growth			
	1935	1936	1937	1938
No fertilizer	175	162	393	.026
Nitrogen	120	.268	.378	.145
Nitrogen + phosphorus	.210	.198	.278	.043
Nitrogen + potassium	.148	.361	.315	.240
Nitrogen + phosphorus + potassium	.236	.325	.400	.381
Differences necessary for significance (Odds 19:1)	—	.061	.039	.061

*Cover Crop Growth:*—A winter cover crop of rye was grown in all plots. Other experiments have shown the importance of phosphorus in growth of the orchard cover crop. The present one is no exception. The cover crops in the treatments lacking phosphorus have been very poor. The omission of potassium did not seem to affect the growth of the rye.

### CONCLUSIONS

Very pronounced potassium deficiencies have developed in Elberta peach trees grown without added potassium fertilizers in a coarse phase of Norfolk sand near Columbia, South Carolina. The trees were planted on newly cleared land in 1929 and have received differential fertilizer treatment since time of planting. Such trees have shown lower yields, improperly developed fruit, less fruit bud development and severe

foliage symptoms. The deficiency symptoms did not develop until the trees had produced two crops of fruit, but thereafter became increasingly severe in each succeeding year. When the trees were in their seventh bearing season, the minus-potassium trees gave no better performance than the trees that had received no fertilizer of any kind.

The omission of phosphorus has not resulted in such striking differences although the no-phosphorus trees have been significantly lower in yield, in annual increase of trunk cross-section area and in fruit bud development. The principal difference in the no-phosphorus plots has been their failure to grow a normal rye cover crop. There has been no definite foliage symptoms in the minus-phosphorus trees other than an abnormally dull dark green coloration of the leaves.

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## Some Effects of Winery Distillery Waste on Soil and Plants

By E. L. PROEBSTING and H. E. JACOB, *University of California, Davis, Calif.*

THE repeal of prohibition ushered in a great revival of wine making in California. Coincident with it there developed a number of problems jointly concerning growers and wineries. One of these problems was the disposal of various types of winery wastes, and especially of the de-alcoholized wine from the production of fortifying alcohol and brandy. Many millions of gallons of this material must be disposed of. Dumping into rivers is frowned on by public health and fish and game departments. Natural decomposition of the material in sumps gives rise to odors that are highly objectionable, particularly in populous areas. Its use mixed with irrigation water in orchards and vineyards was suggested. This report is the result of investigating this last possibility.

A survey of the major wineries of California revealed the fact that distillery "slop" is toxic to trees and vines when applied in large quantities. Examples of death of many species were found. The effects might be found at considerable distances from the place of application if an impervious layer prevented vertical but encouraged lateral movement. In one location it was reported that vines were killed in a strip over a mile long where the underground movement followed the surface of a hardpan layer. It is obvious that contamination of wells might occur if there is no impervious substratum between the surface of the soil and the water-bearing gravel. It appeared from the survey that land disposal of the untreated distillery waste was a dangerous practice.

Experiments were instituted to try to determine the nature of the toxic agent. Analyses<sup>1</sup> of the fresh material showed the following composition: alcohol 0.00 to 0.2 per cent; total solids 0.7 to 2.5 per cent; organic solids 0.46 to 2.0 per cent; total acid (as tartaric) 0.25 to 0.50 per cent; volatile acid (as acetic) 0.018 to 0.047 per cent; pH 3.7 to 4.0; total N 0.017 to 0.038 per cent; total P 0.035 to 0.050 per cent; total K 0.09 to 0.12 per cent. Sunflowers were planted in flats in the greenhouse and given repeated applications of distillery effluent. Lesions developed at the base of the stem and severe root injury occurred after a lapse of 6 to 28 days. The severity of injury was lessened by re-fermenting the material, which contains up to 1 per cent soluble organic solids, or by adding lime, or by dilution. No injury was found with dilution of 10:1. These results were interpreted as indicating an indirect rather than a direct effect, i.e., the development of unfavorable conditions some time after the application rather than immediate toxicity as a result of materials contained in the fresh waste. It was shown by using a pyrex still that metals, especially copper, that might be removed from the usual equipment, were not responsible for

<sup>1</sup>The authors are indebted to A. E. Gilmore for certain of the analytical data presented.

the damage. Acetic acid of the order of magnitude found in these samples did not produce the symptoms caused by "slop" treatment.

In the fall of 1937, the soil near a small sump in which "slop" was being dumped was explored where trees and vines were dying. Holes were bored deep enough so that liquid from the surrounding soil drained into them and could be collected. This liquid, when applied to sunflowers, was far more toxic than the original material. Death of plants occurred within 24 hours. It was a clear, water-white liquid containing 0.127 per cent  $\text{Fe}^{++}$ , 0.0082 per cent  $\text{Mn}^{++}$ , 0.003 per cent  $\text{Al}^{+++}$ , 0.053  $\text{Ca}^{++}$ , and 0.015 per cent  $\text{Mg}^{++}$ . The pH was 5.2. Free volatile acid was 0.11 per cent and when distilled with  $\text{H}_2\text{SO}_4$  was 0.54 per cent as acetic acid. These results suggested that the toxicity might be due to changes taking place in the soil rather than to the original composition of the slop.

A synthetic inorganic mixture having as nearly as possible the same concentrations of ions was made and applied to sunflowers. They died as quickly and in the same manner as those receiving the drainage water.

Solutions of ferrous sulfate, magnesium acetate and calcium acetate were made with the cations having the same concentrations found in the drainage water. Each of these solutions killed sunflowers within 5 days. It appears that toxic concentrations of both Fe and acetate are present. The possibility of the presence of other toxic materials, organic or inorganic, is not excluded.

A series of plots designed to determine the tolerance of vines to distillery effluent was laid out in the fall of 1937. Various amounts and dilutions were proposed. Unexpected difficulties prevented the completion of the experiment, but it was found that where about 3 inches of the material had been added the vines were definitely injured. The growth in 1938 was short, nodes close together, and there was a reduction in the number of buds to start. Roots were injured to a depth of at least 4 feet but not dead when examined May 14, 1938. Injury to the roots appeared as a discoloration of the outer xylem and portions of the bark.

Observations made on a large vineyard where the waste was mixed with the irrigation water (20 gallons per minute de-alcoholized wine to 800 g.p.m. water) indicated that this method of disposal was possible if great care was used and high dilution practiced. Another vineyard growing on very open, gravelly soil had heavy applications without serious damage, perhaps because so little was retained in the root zone that it could be readily decomposed aerobically instead of anaerobically as seems to be the case in heavier soils.

Another winery started running the still effluent into a low-lying portion of a vineyard at the beginning of the season in 1937. The vines at that time were in good condition. The soil of this vineyard — a deep, sandy loam — was sampled at intervals for a year in order to follow the changes induced by the added waste. Samples were taken in 1-foot increments to a depth of 4 feet. The first samples were taken December 6, 1937, about 10 days or 2 weeks after the end of the distilling season for this winery. At this time the roots of the vines in the area to

which the waste had been added were dead. None of these vines produced shoots in the following spring. The suspended matter in the waste had been filtered out by the surface soil, leaving a thick sludge on the surface. This was scraped away before sampling. The water table at this time was below 4 feet from the surface.

The first sample was divided into three portions from each depth. The first portion was placed in a flat and sunflowers transplanted to it the day following sampling. The second portion was treated with lime at the rate of 0.5 per cent CaO at the same time. It was then allowed to stand until December 21, when it was seeded with sunflowers. The third portion was allowed to dry out on a table in the greenhouse until the same date, then placed in flats and seeded. Injury was evident in the first series in 6 days. Most of the plants were dead before the other series were started. Both the drying and aeration and the liming reduced but did not eliminate the damage. The first series was re-seeded at the same time the second and third were planted. These plants survived with a few exceptions for 5 weeks, when the experiment was terminated. The roots were largely confined to the top 1 inch of soil.

Additional samples were secured January 7, March 28, May 14, June 16, July 20, September 6, and October 10. These samples showed a gradual recovery of the soil toward a normal condition, as is shown in Table I. The color returned to brown instead of gray. The foul odor that had been evident gradually disappeared, and with these changes the development of the sunflowers in the test flats became normal. At the same time, oxidation of inorganic materials was also in progress, as indicated by the presence of ferrous iron in the early samples and its gradual disappearance as the season progressed. These recovery symptoms developed first in the surface soil, and gradually appeared at lower depths. The pH shifted from less than 5 to above 7 during the same period. At the time of the last sampling, recovery was nearly complete to a depth of 4 feet. Soil color and odor had not quite reached the original state below the second foot. Ferrous iron was barely detectable in the third and fourth foot samples. In the samples taken January 7 to May 14, the clay fraction of the soil was very highly dispersed.

It seems, from this instance, that in an open, well-drained soil which has been saturated with wine distillery waste that sufficient recovery of the soil will occur within 6 months to permit a shallow rooted annual to grow, but that a year or more must elapse before a deep rooted crop could be planted with safety. Furthermore, a probable permanent reduction in soil fertility is indicated by the following figures for replaceable bases in the treated and normal soils.

Soil	Treated				Normal			
	0-1	1-2	2-3	3-4	0-1	1-2	2-3	3-4
Depth (feet).....	0-1	1-2	2-3	3-4	0-1	1-2	2-3	3-4
Ca .....	640	680	480	1040	1240	760	600	660
Mg .....	150	160	120	170	190	160	160	180

These figures suggest that the action of the decomposing waste has brought considerable amounts of replaceable bases into solution, pre-



TABLE I—CHANGES FOUND IN SOIL DURING YEAR FOLLOWING APPLICATION OF DISTILLERY EFFLUENT TO VINEYARD

Date	Depth (Feet)	Color	Odor	Fe <sup>++</sup> in Acid Extract	Fe <sup>++</sup> in Water Extract	NO <sub>3</sub>	NO <sub>2</sub>	pH	Notes on Sunflower-ers in Plots
December 6, 1937	0-1	Gray	Foul	—	+	—	—	4.8	Dead 6 days
	1-2	Gray	Foul	—	+	—	—	4.8	Dead 6 days
	2-3	Gray	Foul	—	+	—	—	4.8	Dead 6 days
March 28, 1937	0-1	Brown	Normal	+	+	+	+	7.0	Slight injury
	1-2	Gray-brown	Slight	+	+	0	0	6.3	Newly normal
	2-3	Gray	Foul	+	+	0	0	5.7	Slight root injury
June 16, 1938	0-1	Brown	Normal	+	+	+	+	7.0	Normal
	1-2	Brown	Slight	+	+	+	+	7.5	Slight root injury
	2-3	Gray-brown	Moderate	+	+	+	+	6.4	Slight root injury
October 10, 1938	0-1	Brown	Normal	+	+	+	+	7.6	Greater root injury
	1-2	Brown	Normal	+	+	+	+	7.5*	Normal
	2-3	Gray-brown	Slight	+	+	+	+	7.5*	Normal
	3-4	Gray	Moderate	+	+	+	+	6.9*	Normal
								7.2*	Normal

Fe<sup>++</sup> and NO<sub>3</sub> determined colorimetrically throughout, qualitative only.

\*pH not determined. Figures for September 6, 1938 set of samples.

†Parts per million.

sumably in exchange for H, and that leaching has occurred. It seems probably that serious chemical and physical deterioration can be expected if repeated treatments of this nature are given to a soil.

### CONCLUSIONS

The results of observation and experiments through a 4-year period show that application of de-alcoholized residue from wine distilleries to orchards or vineyards is a dangerous practice, usually resulting in the death of the plants, unless highly diluted. The cause of death is not toxic substances in the waste itself, but is materials produced during the decomposition of the "slop" in the soil under nearly anaerobic conditions. Direct evidence of organic poisons is lacking although this possibility is not excluded. Concentrations of inorganic salts such as were brought into solution from the soil by the decomposition, especially ferrous iron, have been shown to be sufficient to kill plants in soil in pots in 24 hours. One soil made unfit for crop use in this manner in the fall of 1937 had lost its toxicity, at least for sunflowers, to a depth of 4 feet by the early fall of 1938. It is believed that some permanent damage to the soil in the leaching of nutrients has been done.

## Some Results from Orchard Irrigation in Eastern Nebraska<sup>1</sup>

By C. C. WIGGANS, *University of Nebraska, Lincoln, Nebr.*

TWO earlier papers (1, 2) have presented indisputable evidence that orchard trees growing on the deep, porous loess soils of eastern Nebraska remove available moisture from the soil to great depths. Furthermore, the rate of depletion exceeds the annual rainfall, thus definitely limiting the useful life of the orchard to that period preceding total withdrawal of available moisture. Additional evidence is presented in a third paper (3) which also indicates that the depletion rate is correlated with the age and spacing of the trees.

Facing these facts and confronted with the situation that moisture very soon would be a limiting factor in the experimental orchard at Union, the Department of Horticulture of the University of Nebraska made arrangements to supply additional water for the use of these apple trees. A rotary pump, powered by an electric motor, lifts water from a nearby creek and by means of a 5-inch pipe distributes it through the orchard. Distribution to individual trees is by means of lateral ditches and a basin under each tree. The pumpage rate is approximately 9,000 gallons per hour or slightly over 3-acre inches per day. Pumping was begun about July 1, 1937, and continued until December 1. During 1938 the pumping season began April 1 and closed on November 30.

During 1937 the main object was to prepare some selected areas for later experimental use by replacing subsoil water which had been removed by the 20-year-old Delicious trees on these areas. A further objective was to supply generally to the entire planting, aside from check blocks, some water to supplement the annual rainfall which for the past several years had been far below normal. Approximately 6 inches were thus applied the first season. In 1938 nearly all the water pumped was used as a general application, 9 to 10 inches beyond annual rainfall thus being made available for tree use.

Data taken have been of several types but only two types, fruit size and moisture usage, are mentioned in any detail here. General appearance of trees and fruit was much superior on the irrigated areas and recovery from severe hail damage inflicted 2 years earlier was much greater. From the standpoint of the producer, however, fruit size and yield are of much greater significance than mere appearance of foliage. In Table I the sizes of fruit produced by comparable trees from the irrigated and dry land blocks are given. In general all trees carried a good crop and yields did not vary widely between the irrigated and unirrigated trees. From 25 to 40 bushels of each variety were used in securing these size data.

The evidence seems to be sufficient to justify the conclusion that the

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<sup>1</sup>Published as Scientific Paper No. 224 Journal series from the Nebraska Agricultural Experiment Station, with the approval of the director.

TABLE I—EFFECT OF ORCHARD IRRIGATION ON PERCENTAGES OF VARIOUS FRUIT SIZES (DIAMETER IN INCHES) 1938

Variety	Dry Land				Irrigated			
	Less Than 2¼ (Per Cent)	2¼ to 2½ (Per Cent)	2½ to 2¾ (Per Cent)	Over 2¾ (Per Cent)	Less Than 2¼ (Per Cent)	2¼ to 2½ (Per Cent)	2½ to 2¾ (Per Cent)	Over 2¾ (Per Cent)
Duchess . . . . .	57.0	35.1	7.1	0.8	16.0	45.3	29.6	9.1
Wealthy . . . . .	79.6	19.5	0.8	0.1	20.1	41.7	23.9	14.3
Virginia Beauty . . . . .	45.3	48.6	6.1	0.0	3.8	15.7	24.0	56.5
Delicious . . . . .	8.0	28.9	38.0	25.1	1.6	8.1	21.1	69.2
Grimes . . . . .	78.3	19.5	2.2	0.0	6.5	29.8	40.3	23.4
York . . . . .	4.8	13.4	21.6	60.2	0.1	8.3	20.9	70.7
Winesap . . . . .	36.9	29.7	28.2	5.2	16.2	36.1	32.5	15.1
Average . . . . .	44.3	28.1	14.9	13.1	9.2	26.4	27.6	36.9

supplemental moisture was quite influential in increasing fruit size. Irrigation reduced the proportion of fruit less than 2½ inches in diameter from 44.3 to 9.2 per cent and increased materially the proportions of the two larger sizes.

In order to get at the question of how much water an apple tree really needs, a project was begun in June 1937. An area of slightly over ½ acre containing 16 Delicious trees 19 years old and spaced 30 by 33 feet, had been so prepared that water distribution would be uniform.

Soil samples were taken by the method described in an earlier paper (1). Water was added in July so that the soil was filled to field capacity to a depth of 30 feet, thus replacing all soil moisture which had previously been removed by the trees and by other crops or by surface evaporation. A total of 43 inches of water was added to this block of trees.

Soil samples taken at intervals after the water application showed that by the late fall of 1937 moisture conditions to a depth of 30 feet had become stabilized. Samplings were continued at intervals of approximately 1 month during the season of 1938. Only a few of these data are reported in Table II. Included also are data relating to the hygroscopic coefficient (H.C.), the rainfall, the calculated available reserve, and the net change in soil moisture content. The reserve and changes are calculated by assuming that 1 inch of water is equivalent to 6.5 per cent of the weight of a cubic foot of soil, that is, a change of 3.3 per cent in the average water content of a 30 foot column of soil is equivalent to a change of 15.2 inches ( $30 \times 3.3 \div 6.5 = 15.2$ ).

Inspection of data in Table II indicates that the rainfall of 22.68 inches occurring between November 9, 1937 and October 26, 1938 apparently was insufficient for the total needs of the trees, the competing annual crops and evaporation losses. Just how much water was needed for the two latter purposes was undetermined. However, between these sampling dates, the amount of water used for all purposes was 22.68 inches + 15.2 or a total of 37.88 inches. In the earlier paper (2) comparable figures are given as 31.24 inches, figures not so far apart when one considers the difference in age and size of the trees and also some difference in rainfall.

TABLE II—MOISTURE CONTENT OF SOIL AT VARIOUS LEVELS AND AT VARIOUS DATES PRECEDING AND FOLLOWING THE APPLICATION OF 43 INCHES OF WATER IN JUNE 1937 TO A BLOCK OF 19-YEAR-OLD DELICIOUS APPLE TREES

Depth (Feet)	Soil Moisture Percentages at Various Dates				
	H. C.*	June 18, 1937	August 25, 1937	November 9, 1937	October 26, 1938
1 to 5	10.6	21.8	26.4	25.1	17.6
6 to 10	10.4	17.7	27.0	26.0	21.1
11 to 15	9.9	17.9	27.7	27.8	24.3
16 to 20	9.2	18.8	27.2	29.5	25.4
21 to 25	8.7	20.1	25.7	25.9	25.1
26 to 30	9.9	18.0	19.5	19.0	20.1
Average	9.8	19.0	25.6	25.6	22.3
Water added (in interval) rain-fall (inches) . . . .	—	—	8.56	1.72	22.68
Irrigation (inches) . . . .	—	—	43.00	—	—
Calculated available reserve (inches) . . . .	—	42.5	72.9	72.9	57.7
Gain or loss (inches)	—	—	+30.4	—	-15.2

\*The hygroscopic coefficient of the soil under consideration is only slightly (1 to 2 per cent) below the permanent wilting point.

### CONCLUSIONS

Data based upon 1 year's results show a decided beneficial effect upon fruit size from the application of approximately 16 inches of irrigation water (6 inches in 1937 and 10 inches in 1938) to 20-year-old Delicious apple trees.

Soil moisture data confirm earlier conclusions that water necessary to maintain the tree and competing crops and surface evaporation is greater by 15.2 inches than the intervening rainfall of 22.68 inches. The greatest loss of moisture occurred in the upper 20 feet where 30 feet of soil had been filled to field capacity by irrigation. Approximately  $\frac{3}{4}$  acre inch of water (80 to 85 tons) was used by each tree under the conditions existing in this orchard during the growing season of 1938.

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## A Method by Which Trees May be Grown with Their Roots in Two Soils

By N. L. PARTRIDGE, *Michigan State College, East Lansing, Mich.*

THE root systems of mature apple trees grown on most types of soil extend beyond the spread of the branches and often penetrate to considerable depths where the subsoil is well drained and of rather open structure. In some cases, apple root penetration to depths of 20 feet or more has been recorded. Pronounced variations are found in the character of the substratum within the limits of root development, particularly in areas where the soil is of glacial origin. Some of the factors influencing tree growth, namely, the pH, the available moisture, nitrogen, phosphorus, potash and calcium carbonate usually vary considerably in the different portions of the soil mass reached by the roots of fruit trees growing on most Michigan soils. The tree as it grows in the orchard is a response to the ability of that portion of the soil complex reached by its roots, to supply the materials necessary for its growth.

Moisture is necessary for the growth of the tree, not alone to maintain its turgidity, but also because water is the agent through which the mineral nutrients present in the soil are transferred to the root system. During periods of dry weather, moisture is removed from the soil, but its decrease does not proceed at uniform rates throughout all portions of the soil mass reached by the root system. Consequently, the moisture content often is very low in those portions of the soil mass which are most thoroughly exploited by the roots (in some instances the moisture may be at or below the permanent wilting point) while other portions continue to supply large quantities of water. The lack of water in the dry portions of the soil mass will prevent or at least very much reduce the intake of nutrients from that part of the soil volume. It seems possible that the tree might suffer from a deficiency of some mineral element actually present in the soil provided it is available only in the dry portion of the soil and provided further that it is stored in the tree in insufficient quantity to supply the needs of the tree during the entire period of the drought.

Ordinarily, moisture first becomes deficient in the upper horizons of the soil, since this is the region which is usually most exploited by fruit tree roots, as well as by those of any grasses or weeds that may be present in the orchard. This upper portion of the soil, the A horizons, almost invariably contains the most abundant supply of nitrogen and sometimes the highest percentage of available phosphorus and potash per unit volume of soil. Since the supply of nitrogen is frequently limited largely to the A horizons of Michigan soils, this element would appear to be most likely to become deficient during droughts unless sufficient quantities had been stored previously in the tree.

Auchter (1) has shown that the lateral movement of nitrogen is negligible in the apple tree. On the other hand Furr and Taylor (2) have shown that the cross-transfer of water in lemon trees is very

rapid. The results reported below show this same rapid cross-transfer of water also occurs in apple trees. The technic described below was designed to reproduce under control, the conditions found in our orchards when the fertile A horizons become dry during droughts, and the supply of nitrogen from the soil is prevented or reduced materially.

### METHODS

Galvanized iron boxes 18 inches wide, 18 inches long and 24 inches deep were made and joined together in pairs. One box of each pair was fitted with a slide which could be removed thus permitting the soil to be washed out of that box. Drainage holes were made in the bottom of each box. Dwarf McIntosh trees were then set astride the partition between the two joined boxes, a channel being sawed upward through the root system and well into the trunk of each tree, and the whole area surrounding the cut was covered thickly with grafting wax. All the boxes were then filled with surface soil from a garden spot, a loamy sand, and the trees were grown for 3 years without differential treatment. All of the 12 trees grew thriftily and gave no indication of being disturbed by their environment. Water, of course, was furnished as needed by the trees. At the conclusion of the preparatory treatment, the soil was washed out of all the boxes provided with slides, that is from one box of each pair, and replaced by sand taken from the beach of Lake Michigan. This sand was low in available nutrients, especially in nitrogen. Fig. 1 is a reproduction of a photograph taken after one of each pair of compartments was emptied and shows the construction

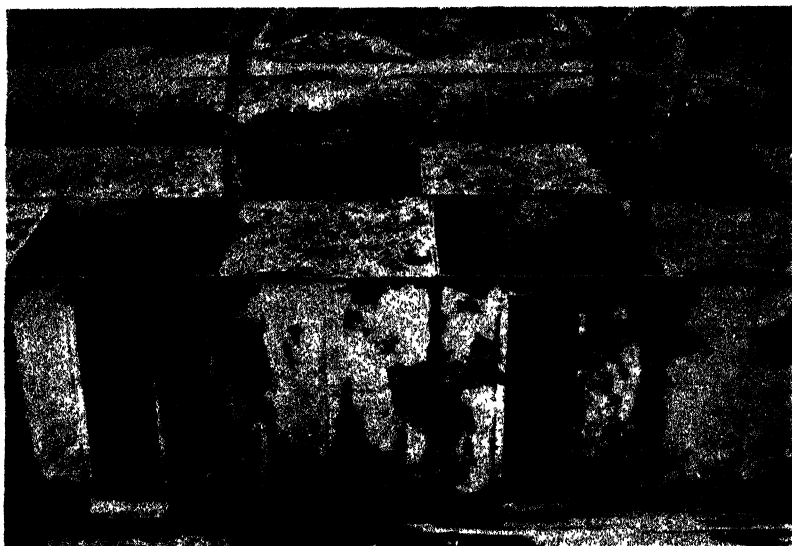


FIG. 1. Photograph showing dwarf McIntosh apple trees grown with roots in two compartments for 3 years. The soil has been washed out of one compartment of each pair preparatory to refilling it with lake sand.

of the boxes with the tree in place on the center partition with half the root system exposed.

The trees were divided into three groups of four each, on a basis of their vigor, individuals which were very vigorous, intermediate, and of comparatively weak growth being placed in each group. Tin covers were made and set over the boxes or compartments from which the garden soil had not been removed; thus this fertile soil quickly became dry as the roots removed the moisture from the soil, none being able to enter these compartments. The three treatments were: (a) Both compartments uncovered and receiving water but no fertilizer; (b) the loam covered and hence dry, the sand uncovered and receiving water but no fertilizer; (c) the loam covered and hence dry, the sand uncovered and receiving water and also fertilizer, 1 ounce of sodium nitrate on May 1 and another ounce on June 1. All of the trees were watered as needed. The cross-transfer of water in those trees whose root systems received water on one side only was sufficient so that no moisture deficiency was observed in any part of any of the trees.

The trees bloomed heavily and set a light crop of fruit. At no time during the season were any differences in color of foliage or in rate of shoot or fruit growth observed on any of the trees. Apparently, a sufficient supply of nitrogen had been stored in the trees to supply their needs throughout the season; the trees in the second group were able to secure very little from the sand, and the nitrogen in the loam was no longer available after the soil became dry. Doubtless, the fact that the trees had received ample supplies of nitrogen during the years that they had grown in this fertile soil accounted for the abundant reserves. Although no nitrogen deficiencies developed during the course of this season, it does not offer conclusive evidence that such a lack will never result from drought. On the contrary, if the nitrogen reserves in these trees had been low instead of high, such a deficiency would probably have been observed.

The experiment was considered concluded at the end of the season's growth. However, the tin covers were left in place and the trees received sufficient water to supply their needs throughout the following season; no fertilizer was applied. The color of the foliage indicated that the nitrogen reserves had been reduced the preceding season in those parts of the trees which would normally have received their nitrogen from the dry loam or unfertilized sand. Thus the foliage of the entire trees in the second group was yellowish, since little nitrogen was supplied to either half the preceding year. The trees of the first and third groups, however, showed marked color differences, the foliage on that portion of each tree of the first group which was supplied with nutrients from the compartment containing the loam were normal green in color but that supplied by the unfertilized sand was quite yellow. In the third group, the foliage on that portion of each tree which was supplied with nutrients from the compartment containing the fertilized sand were normal green in color but that normally supplied by the dry loam was quite yellow.

This method of growing trees with their roots in two compartments offers a means for making controlled studies of variations in the supply



of nutrients such as those found in nature where the root system exploits soil masses with very different characteristics. Nitrogen studies in particular may be studied in this manner. However, studies might be made of the supply of other elements which are not subject to cross transfer in the trunks of trees.

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# Manganese Deficiency in Citrus in Florida

By A. F. CAMP and MICHAEL PEECH, *Citrus Experiment Station,  
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**R**ESPONSES to the use of manganese in citrus in Florida were reported by Skinner, Bahrt and others (1, 4, 5, 6) prior to the identification of symptoms associated with its deficiency in the field, the responses being judged on improved tree condition, better fruit color, and increased production. Its earliest use was associated with the marl soils in the coastal areas and "marl frencing" was commonly accepted as a symptom of manganese deficiency. Its use spread to the acid sandy soils due to the further work of Bahrt and his co-workers but was not associated with any particular symptom. The definite leaf symptoms associated with manganese deficiency in citrus in the field were first described by Camp and Reuther (2) in 1937, having been identified in plots conducted for the study of symptoms of nutritional deficiencies in citrus. Some of the plots were on very light acid sands and confirmed the previous evidence that manganese was generally deficient on such soils. The symptoms had probably gone unidentified previously due to the widespread occurrence of zinc deficiency (frenching) which has a somewhat similar pattern but much more pronounced, thus tending to mask manganese deficiency symptoms. At the time the manganese deficiency symptoms were identified, zinc sprays had been widely used and a survey showed that manganese deficiency was distributed generally throughout the citrus belt. At that time the symptoms were most commonly found in groves that had received zinc spray to correct frencing and later results have shown that zinc and manganese deficiencies are induced by much the same soil conditions.

The discussion above applies entirely to manganese deficiency as it occurs in the field in Florida. In 1932 Haas (3) described manganese deficiency of citrus (lemon and rough lemon) as it occurred in water culture. While the leaves were described as chlorotic the description was not sufficiently detailed to determine whether they were similar to those found in the field in Florida. Other phases described by Haas such as the premature abscission of young leaves, gum spotting of leaves and twigs, and extreme chlorosis of leaves have not been identified in the field. This may be due to environmental conditions or to the fact that manganese deficiency as extreme as that obtained by Haas never occurs in the field.

## DESCRIPTION OF SYMPTOMS

As the young manganese deficient leaves unfold they show a network of fine green veins on a light green background but this stage is difficult to separate from zinc deficiency and is not commonly recognized in the field. The symptoms most commonly noted are evident just as the leaves have expanded to full size, being characterized by light green areas between the main veins and dark green areas along the veins

(Fig. 1). The pattern is somewhat similar to that associated with zinc deficiency but much less definite both as to color and pattern. As the

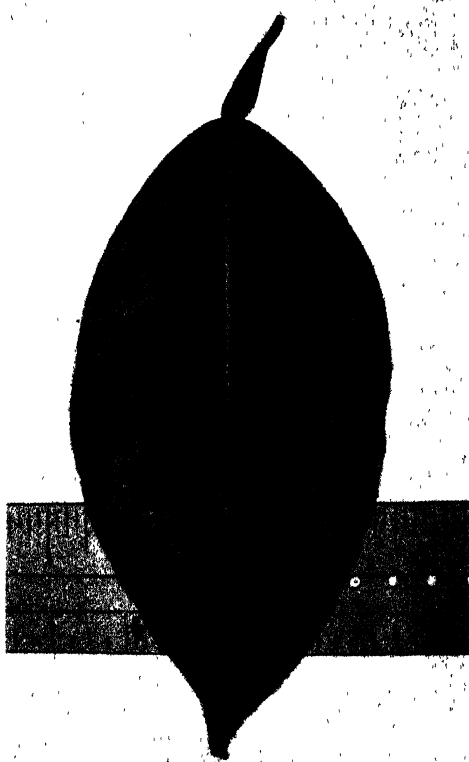


FIG. 1. Pattern of manganese deficiency on citrus leaf.

leaves harden up the pattern may gradually disappear. This disappearance is apparently associated with a supply of manganese too low to supply a flush of growth but sufficiently high to supply the tree after the strain of producing a flush is over. In more pronounced cases the pattern is retained throughout the life of the leaf, the light green areas taking on a light bronze color fading later to a dull whitish cast or in milder cases remaining a dull light green. The dullness, in contrast to the shiny surface of normal leaves, is characteristic of the leaves showing the symptom and is one of the distinguishing characteristics.

The affected leaves retain their normal outline and do not show the narrowing so characteristic of zinc deficiency nor is the bushy growth with

very short internodes evident. In severe cases there is a reduction in growth and foliage, and applications of manganese produce a decided growth response. Deficient trees usually produce fruit with a lighter color than is normal for the soil and variety combination. In general, the symptoms are less evident than those of zinc, copper or magnesium deficiencies and harder to define and recognize.

As previously mentioned, zinc deficiency and manganese deficiency are commonly associated. If the zinc deficiency is predominant the manganese deficiency may be almost completely masked; and where manganese deficiency is predominant the effect is to intensify the symptoms of manganese deficiency so that it may be mistaken for zinc deficiency although without the typical narrow leaves of the latter. So-called "marl frecking" is typical of the latter mixture and an application of zinc spray will leave typical manganese deficiency which is much less pronounced than the original symptom.

### CORRECTION

Leaves showing the characteristic pattern will become green if dipped in a dilute solution of manganous sulfate and protected from rain so that the solution is not immediately washed from the leaf. Young leaves respond rapidly with very definite response in 10 to 14 days and become completely green in less than 30 days. Older leaves are somewhat slower to respond although all stages seem to recover satisfactorily. The response can be improved by precipitating the manganese with lime, lime-sulfur or sodium hydroxide and applying a suspension of the precipitated manganese. The correction is quite localized, at least in the early stages. When the apical half of a leaf was dipped, the dipped portion greened up before the remainder showed any correction, although the basal half would later show some degree of correction indicating a slight translocation. When terminal leaves were dipped, however, the leaves immediately above them showed no correction after 6 months.

Correction in the field is commonly obtained by means of soil applications. Sprays give a faster and more complete correction but, like all sprays leaving a more or less inert residue, cause a build-up of scale. Sprays made up using manganous sulfate and hydrated lime or lime-sulfur gave excellent results in less than 30 days during the spring and summer. Manganese sulfate solution gave evanescent results as a general rule. This was due both to the difficulty experienced in wetting the leaves and to the washing effects of heavy dews and rains. When such solutions were used with liberal amounts of a colloidal spreader and sticker which retained it on the leaf, the results were almost equal to the precipitated manganese. Manganese has given a satisfactory response when combined with bordeaux, neutral copper sprays, wettable sulfur or lime-sulfur and where manganese sprays are used commercially it is usually in some combination of these.

### VARIETAL RELATIONSHIPS

There seems to be considerable variation in manganese requirements in the citrus group if the symptoms are taken as the criterion. Tangerines and Temple oranges usually show the symptoms more generally and quickly than do oranges and grapefruit. In adjoining rows in the same grove tangerines or Temples may show severe symptoms while oranges and grapefruit in the same grove are free of it, and grapefruit commonly show the symptoms before oranges although this is not nearly so definite. There also seems to be some varietal variation within the same genus but further study is needed on this point.

### SOIL RELATIONSHIPS

Manganese deficiency has commonly been associated with alkaline soils and, as previously mentioned, its first extensive use on citrus in Florida was on such soils. However, manganese deficiency is probably wider spread on light acid sands in Florida than it is on the alkaline soils although seldom found in as severe a form. In Table I will be found analyses of citrus soils on which trees showing the typical symp-

toms are growing. The analyses were made using one *N* neutral ammonium acetate as the extracting solution and standard methods for determining replaceable bases. The first group includes typical examples of alkaline coastal soils, the alkalinity being due to an excess of marl. Such soils must be treated yearly with manganese sulfate or the trees sprayed with a suitable manganese spray to keep them in heavy production. The first two soils were from groves that had been treated regularly with manganese sulfate on the soil. Number 1 had received an application of 5 pounds per tree of 65 per cent manganese sulfate applied 13 months prior to taking the sample. The application was made over a circular area slightly larger than the spread of the tree and the soil samples taken in the same area. The material was thus distributed at a rate of about 1000 pounds per acre of manganese sulfate over the area sampled but only .8 pound of manganese was still in the available form at the time the sample was taken. Sample No. 2 was from a grove that had received similar applications for 3 consecutive years, the last application having been made about 1 year prior to sampling. In the case of sample No. 3 the amount of manganese applied could not be determined as it had been included in the fertilizer and the grower did not have complete records. It will be noted that the symptoms were medium to severe in all cases in spite of former manganese treatment and due to the period lapsing since the last application. Experiments have shown that the best results are usually obtained from applications in January or early February, the trees showing almost complete recovery during the spring flush of growth which usually occurs in these areas about the end of February. By fall the symptoms have started to reappear and by 12 months after the application have become general. While the rate of manganese fixation has not been accurately determined it is evidently very rapid in such soils.

TABLE I—EXCHANGEABLE BASES OF SOME TYPICAL FLORIDA CITRUS SOILS

Sample Number	Soil Type	Depth (Inches)	pH	Ex. Cap. (M.E./100 Gms of Soil)	Pounds per acre 6 Inches of Soil				Mn Deficiency Symptoms
					Ca	Mg	K	Mn	
1	Parkwood loam	0 to 6	7.86	17.9	6,450	347	313	0.8	Severe
		6 to 18	8.19	6.63	2,200	215	195	0.3	
2	Parkwood clay loam	0 to 8	8.31	6.60	2,070	284	210	0.4	Severe
3	Parkwood fine sandy loam	0 to 6	7.81	19.3	7,000	308	416	0.3	
		6 to 18	8.35	4.10	1,330	139	178	0.6	Slight
4	Parkwood fine sandy loam	0 to 6	6.44	11.6	4,350	117	198	1.8	
		6 to 14	6.66	4.7	1,760	52	67	0.6	None
5	Parkwood sandy loam	0 to 8	5.46	6.95	1,300	227	196	9.3	
		8 to 18	6.50	5.72	1,210	347	93	0.8	None
		18 to 24	8.16	14.0	3,950	950	200	0.6	
6	Lakewood fine sand	0 to 6	6.00	3.24	880	54	73	1.2	Severe
		6 to 12	5.54	0.92	101	5	30	0.1	
		12 to 18	4.54	1.44	65	6	46	0.1	Medium
7	Leon	0 to 6	5.25	7.01	1,601	147	125	0.75	
		6 to 12	4.70	4.35	735	73	125	0.34	Severe
8	Norfolk fine sand	0 to 6	5.44	1.85	194	5	55	1.0	
		6 to 18	5.01	1.11	30	5	19	0.3	Severe
9	Norfolk fine sand	0 to 6	4.54	2.47	202	3	44	0.8	
		6 to 18	4.44	1.14	36	3	16	0.1	None
10	Norfolk fine sand	0 to 6	5.45	3.70	1,065	27	130	17.0	
		6 to 18	5.10	1.24	194	6	43	0.9	None
11	Norfolk fine sand	0 to 5	4.85	2.20	202	22	37	4.5	
		5 to 18	4.56	1.16	22	3	18	1.7	None

It should be noted in connection with the first five samples that this soil series (Parkwood), in its virgin state, has an acid "A" horizon of variable depth underlain by marl. The soil is ridged for planting and if the acid layer or "A" horizon was sufficiently deep so as to form the major portion of the ridge then the soil in the ridge is acid but if the "A" horizon was shallow then the ridge is alkaline due to the inclusion of marl. In the latter case manganese deficiency is general, and in the former case it seldom occurs.

Alkaline soils commonly show zinc deficiency (frenching) in addition to manganese deficiency. Camp and Reuther (2) have pointed out that zinc deficiency is common in soils above pH 6.0 probably due to fixation. Manganese behaves similarly but the pH at which it is fixed appears to be somewhat higher. Consequently on alkaline soils both deficiencies commonly occur together and both elements need to be applied to correct the trouble.

The Norfolk soils are by far the most extensively used citrus soils of the state, and typical analyses are shown in samples Nos. 8 to 11 inclusive. Because of their low exchange capacity these soils are poorly buffered and over-liming often brings on both zinc and manganese deficiencies. Also under the influence of acid fertilizers and sulfur incident to pest control, the pH can be rapidly lowered to 5.0 or lower with the resultant loss of nutrients by leaching. Under the latter condition manganese, zinc, copper, and magnesium rapidly become deficient unless supplied. Samples Nos. 8 and 9 represent typical examples of manganese deficient soils of this series. Number 10 shows the highest amount of manganese found in examining soils from about 100 groves on this soil type. Most grove soils in this series contain less than 5 pounds per acre but the margin between a deficient and an ample supply has not been established.

### CONCLUSION

Manganese deficiency symptoms on citrus as they occur in the field in Florida were found to resemble the symptoms of zinc deficiency as to leaf pattern but much less pronounced. It can be corrected both by applications of manganese salts to the soil and to the leaves. Its occurrence on both acid and alkaline soils is discussed in relation to the soil analysis.

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## Some Responses of McIntosh Apple Seedlings Growing with the Roots in Various Concentrations of Oxygen

By J. I. DE VILLIERS, *Cornell University, Ithaca, N. Y.*

### ABSTRACT

**T**HE roots and basal parts of the stems of apple seedlings were sealed in quart glass jars in which they had been growing. An air-nitrogen mixture of known oxygen concentration was let in at the top of the jar, drawn through the sand (or soil), and past the roots in a slow, continuous stream and was withdrawn through an outlet tube which extended to the bottom of the container.

Every response which could be quantitatively expressed showed the effects of poor aeration. For example, the increase in leaf area while under treatment was only very slightly less than normal when the roots were in 10 per cent oxygen but was only one-third of this area when the soil oxygen was reduced to 5 per cent. The reduction in gain of leaf area, due to the leaves being both smaller and fewer than in the controls, continued in the lower oxygen concentrations until in the 1 per cent oxygen lot there was an actual loss in leaf area.

The weights of the entire plants, though not so sensitive a criterion as some of the others, also reflected the depressing effects of poor aeration. Thus in 1 per cent oxygen the growth, as indicated by the green weight, was only 12 per cent of what it was in the well-aerated control. Judged by the dry weights, the depressing effect of deficient oxygen was not quite so severe. In the example just mentioned the dry weight indicated that in 1 per cent oxygen the growth was 35 per cent and in 5 per cent oxygen was slightly more than 50 per cent of that made in 20.6 per cent oxygen. Nevertheless according to the averages of the dry weights of all five series growth was retarded as soon as the oxygen content of the soil air was reduced. Thus, in 15 per cent oxygen there was a 10 per cent reduction and in 10 per cent oxygen a 20 per cent reduction as compared to the controls.

Ash, expressed as a percentage of the dry weight, decreased when the soil oxygen was decreased. As the dry weight formed also was less in deficient soil oxygen the amount of minerals actually absorbed was reduced more than was indicated when expressed as a percentage of the dry weight. In fact, mineral absorption was as much retarded as rootgrowth, and, together with the latter, formed the most sensitive criterion of insufficient oxygen for the roots. Furthermore, below 15 per cent oxygen in the soil air, increase in rootgrowth and increase in the total ash contained in the plant were very nearly directly proportional to the oxygen content of the soil. Thus in 15 per cent oxygen rootgrowth and ash increase were 80 per cent of their respective increases in 20.6 per cent oxygen; in 10 per cent oxygen about 55 per cent; in 5 per cent oxygen about 32 per cent and in 2 per cent oxygen approximately 16 per cent.

# Symptoms of Malnutrition in the Peach Resulting from Various Combinations of Nutrient Deficiencies

By O. W. DAVIDSON, *New Jersey Agricultural Experiment Station,  
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## ABSTRACT

The complete paper will be published in the *Botanical Gazette*.

**O**BSERVATIONS made in New Jersey peach orchards during the past few years have revealed instances in which trees exhibited symptoms of a deficiency of phosphorus and of a base at the same time. In fact, such combinations of nutrient deficiencies seemed to occur more frequently than did deficiencies of phosphorus, potassium, calcium, or magnesium alone. This, however, should not be surprising when one is dealing with orchards located on coastal plain soils, for these soils, in general, are inherently low in nutrients. Moreover, in an acid state they have the capacity to fix considerable phosphorus as relatively insoluble iron and aluminum compounds. Therefore, when coastal plain soils are allowed to become deficient in calcium or magnesium, they are apt to be strongly acid and low in phosphorus. Under such conditions, therefore, acid peach orchards that are deficient in potassium are likely to be deficient in phosphorus also.

In order to study the effects of nutrient deficiencies involving phosphorus and a major base upon the growth and composition of peach trees, a sand culture experiment was established in a greenhouse with small, 1-year-old Golden Jubilee trees, in the spring of 1938. Preliminary tests in 1937 were used to develop suitable nutrient solutions. The following nutrient treatments were used: no potassium — no phosphorus; no calcium — no phosphorus; no calcium plus 2 p.p.m. phosphorus; no magnesium — no phosphorus; no magnesium plus 2 p.p.m. phosphorus. For comparative purposes, peach trees were grown also in complete, no phosphorus, no potassium, and no calcium treatments. All treatments, in turn, were compared with results obtained from nutrient deficiency studies with the peach made at the New Jersey Experiment Station during the past several years.

The results of the studies made in 1938 prove that phosphorus deficiency in peach trees may develop independently of, and may co-exist with a deficiency of potassium, calcium, or magnesium. When such a combination-deficiency occurs, the symptoms exhibited, although each may be readily identified with its deficient element, are, in a sense, a summation of the characteristic deficiency symptoms of each element. The omission of phosphorus from the nutrient treatment always resulted in an increase in pigmentation, and in the formation of narrow, dark ochre-green leaves, almost regardless of whether or not the treatment was also deficient in a base. In all combinations involving a deficiency of phosphorus as well as of a base, however, symptoms of the base deficiency were more prominent than those of the phosphorus deficiency.



At the end of the experiment, the uppermost 6-inch portions of representative active stems were cut from plants in each of the several treatments. These and the midribs of their associated leaves were analyzed separately. The analyses showed that phosphorus was present in approximately the same quantities in plants grown in treatments lacking only phosphorus, as in those grown in treatments lacking phosphorus as well as a base.

# The Determination of Ammonia and Amide Nitrogen in Connection with the Chlorate Method for Nitrogen in Plant Tissues

By E. M. EMMERT, *University of Kentucky, Lexington, Ky.*

## ABSTRACT

The complete paper will be published in *Plant Physiology*.

**I**N previous work with the chlorate method for determining nitrogen in plant tissues, samples were used in which the amounts of ammonia and amide nitrogen were either absent or negligible in relation to the total nitrogen present.

In working with samples containing significant amounts of ammonia compounds or amide nitrogen, it is necessary to accompany the determination with a Nessler test for ammonia. The chlorate oxidation changes all nitrogen in plants to nitrate nitrogen with the exception of nitrogen already in the ammonia form or nitrogen in compounds which readily hydrolyze to ammonia such as amides.

In some studies of nitrogen in plants this may be a decided advantage since this divides the nitrogen into two important groups: (a) Nitrates, alkaloids, proteins and amino acids the nitrogen in which is oxidized to nitric acid and determined by phenoldisulfonic acid; and (b) Ammonia, amides and other readily hydrolyzable nitrogen compounds the nitrogen in which is converted to ammonia and determined by the Nessler test. These are the usual compounds to be expected in plants. Of course small amounts of the rarer nitrogen compounds may be present, but it is pretty certain in the chlorate oxidation that all nitrogen in plants is either oxidized to nitric acid or caught as ammonium sulfate. The same is probably true for all nitrogen compounds in general. It will be shown later that the N in pyridine which is not determined by the regular Kjeldahl procedure was determined by the chlorate method by prolonged digestion with chloric acid.

In the soluble nitrogen test on plant extracts from the more mature conducting tissue of lower petioles of rapidly growing long-day plants, most of the nitrogen is in the form of amino acids or nitrates and for practical use to determine nitrogen deficiencies the Nessler test may be omitted, but for detailed work it should be included. Murneek shows that short-day plants contain considerable amide and  $\text{NH}_3$  nitrogen. Inclusion of the Nessler test enables a more detailed study to be made since after treatment with  $\text{H}_2\text{SO}_4$  and  $\text{NaClO}_3$  the phenoldisulfonic test shows all active nitrogen (amino acids and nitrates) present which is in a form for immediate use in the anabolic processes while the Nessler test shows the reserve nitrogen (amides, especially that in asparagin and other compounds readily hydrolyzed to ammonia). A third group would be free ammonia found by making a direct test on the original extract, but this form is not usually found except in very small amounts in normal plant extracts.

Ammonia is determined in an aliquot of the same solution as used in determining alkaloid, protein, and amino nitrogen by the use of phenol-disulfonic acid in the chlorate oxidation. The ammonia is determined by nesslerization of the neutralized solution. Total nitrogen is found by adding the nitrogen determined as nitrate to that found as ammonia. Total soluble nitrogen in plant extracts is determined in much the same way, with the exception that a rapid procedure may be used in which no heating is required other than the heat generated by fuming sulfuric acid.

By the use of these methods very accurate results were obtained for total nitrogen in pure ammonium compounds, asparagine, aspartic acid, picric acid, and plant extracts. The results also showed an almost exact division into the groups of nitrogen compounds mentioned above, especially in the presence of moderate amounts of sugar. This was especially well brought out by the results on asparagine. The results on plant extracts checked quite well with the Kjeldahl method. By prolonged digestion it was found that the N in pyridine could be determined and that all the nitrogen in ammonium sulfate could be converted to nitric acid if so desired.

# The Potassium Nutrition of Fruit Trees II. Leaf Analyses

By OMUND LILLELAND and J. G. BROWN, *University of California, Davis, Calif.*

THE scorching of the foliage of Agen (French) prune trees and the subsequent dying back of limbs and sometimes entire trees in California appears to be a nutritional trouble in which potassium is a factor. The study of this problem has led to extensive analyses of the mineral content of the leaf and other parts of the tree. That part of the data which might have general application in the problem of potassium nutrition is presented in this paper.

## METHODS

The first sampling was generally made in early June and sampling continued at monthly intervals. On young non-bearing trees sampling was limited to basal leaves of current season's growth. These leaves appeared to have reached full size at the time of the first sampling. In the older bearing trees only spur leaves were selected since these mature early. This was done to eliminate errors which might be due to sampling leaves of different ages. Generally 100 leaves were taken from individual trees, placed in manila envelopes and taken to the laboratory. These were weighed, dried in a dehydrator at 60 degrees C for 24 hours, then re-weighed and ground in a Wiley mill to pass 40 mesh. Four gram samples of the oven dry leaf powder were weighed, ashed and analyzed.

## MATERIALS

Leaves from healthy and scorched areas have been examined; also leaves from fertilized and unfertilized trees. Studies have been made on the effect of fruiting on the K content of the leaf since the scorch seems to be most severe with heavy bearing. Comparisons have been made between pruned and non-pruned trees since severe pruning in some instances appears to be a possible means of controlling the injury. A correlation study of the K content of the leaf of some 350 non-bearing trees and the soil in which they are growing has been made. The seasonal changes in the percentage composition and the seasonal migration of K in the leaf of various fruit and nut tree species all growing in the same horticultural environment have been determined, and a study of the petiole test (1) with leaves of known K content was made.

## SEASONAL CHANGES IN THE K CONTENT OF THE LEAF

*Non-bearing Trees*.—It seemed desirable to establish the seasonal curve for potassium in order to ascertain at what time the K differences, known to exist in two orchards, would be most clearly reflected by leaf analysis. The data in Table I are from prune trees in their third leaf from the Canfield orchard, with a low K content in the 0- to 4-foot depth of 87 ppm as determined by the Neubauer procedure,

and the Stile orchard with 287 ppm. The late sampling fails to distinguish the marked differences in the potassium contents. It is therefore desirable to limit the time of leaf sampling to a period from early June to early August in order to obtain the greater differences. Leaf analyses to establish the potassium status of non-bearing fruit trees should preferably be made in early summer.

It is of interest to further analyze the data in Table I and to attempt to account for the marked falling off in the K percentage in the leaf in the Stile orchard. Additional data are therefore presented in Fig. 1

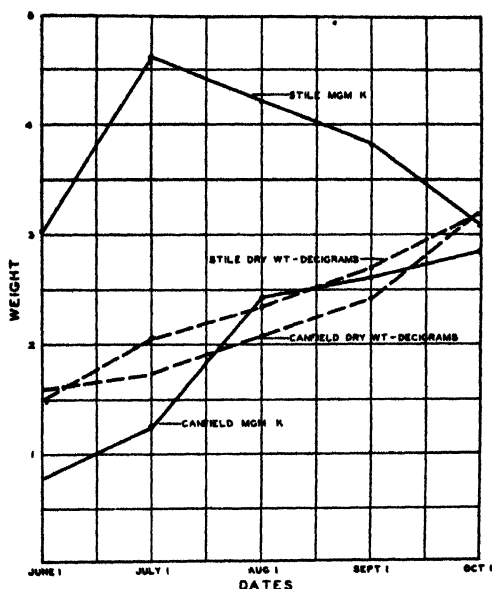


FIG. 1. Changes in the weights of potassium and dry matter in the leaf of Agen (French) prune. The migration of K out of the leaf in the Stile (high K) orchard suggests that leaf analyses to establish the potassium status of non-bearing fruit trees should preferably be made in early summer. The growth of the leaf in the Canfield (low K) orchard as measured by dry weight increase is similar to that found in the Stile (high K) orchard.

and from these the lower percentage values can be largely ascribed to a direct migration of K out of the leaf. There is an increase in the dry matter of the leaf from June to October in both orchards, but there is no movement of K out of the leaf in the low K Canfield trees. Other data from K fertilized trees on the Canfield place (Table I) suggest that the magnitude of the migration is not necessarily correlated with the higher K content and leads one to speculate as to whether or not cultural differences such as irrigation, might be responsible. The two orchards are within 2 miles of each other and their climatic environment is considered identical.

The mobility of potassium in the leaf is characteristic of the element. Heavy crops and severe pruning, presumably through its influence on crop, affect the migration of this element. In contrast, Ca and Mg appear to be little affected. Thus the average Ca and Mg content (18 trees sampled and analyzed individually) in the leaves from the Stile orchard, as found in Table II, show no reduction in either the percentage composition or in the milligrams of Ca and Mg pear leaf throughout the season.

The fixity of calcium and the mobility of potassium are reflected in a study of their solubilities when the dry leaf powder is extracted with water. When 5 grams of leaf powder were extracted with 200 cc

of hot water, the following percentages were found to represent the amount of the cation in water soluble form: K—74 per cent, Ca—2

TABLE I—SEASONAL CHANGES IN THE PERCENTAGE K COMPOSITION OF PRUNE LEAVES IN 1935 (3RD LEAF)

Orchard	Per Cent K in Dry Leaf Matter				
	June 1	July 1	August 1	September 1	October 1
Canfield (low K) . . . . .	.49	.70	1.15	1.02	.90
Stile (high K) . . . . .	2.04	2.26	1.86	1.40	.97
Canfield (K fertilized) . . . . .	2.79	3.62	3.40	2.43	2.17

per cent, Mg—50 per cent. The study included samples taken early and late in the season and from several orchards. Somewhat larger amounts could have been obtained with more complete extraction, but the same relationship would be maintained. The high water solubility and the contrasting behavior of magnesium and potassium is also of interest. Potassium varies probably more than any other cation with the physiological changes within the plant. The comparison and interpretation therefore of any potassium data should be made with this in mind. This will be shown further.

TABLE II—CA AND MG CONTENT OF THE LEAF OF NON-BEARING PRUNE TREES STILE ORCHARD IN 1935 (3RD LEAF)

	June 1	July 1	August 1	September 1	October 1
Per Cent Ca . . . . .	2.09	2.60	3.43	3.53	4.17
Mgm Ca . . . . .	3.12	5.34	7.92	9.70	13.3
Per Cent Mg . . . . .	.57	.73	.91	.98	1.11
Mgm Mg . . . . .	.85	1.54	2.10	2.70	3.54

Despite this independent behavior of Ca and K which suggests a marked difference in their function, a reciprocal relationship is evident when leaves of K fertilized trees are compared with checks. The data in Table III are based on a study of eight adjacent trees, four of which were fertilized with K. No differences existed in the appearance of the trees at the time these samples were taken.

TABLE III—THE EFFECT OF AN INCREASED POTASSIUM SUPPLY IN DECREASING THE CA AND MG CONTENT OF THE LEAF (CANFIELD ORCHARD)

Treatment . . . . .	Per Cent in Dry Leaf Matter					
	June 4			July 17		
	K	Ca	Mg	K	Ca	Mg
K fertilized . . . . .	3.16	1.18	.21	3.60	1.59	.22
Check . . . . .	1.24	1.74	.46	1.66	2.61	.65

These and other unpublished data clearly demonstrate that an increase in potassium in the leaf produces a reduction in Ca and Mg content. The magnitude of the reduction is 30 to 40 per cent for Ca and 40 to 50 per cent for Mg. Since all the trees appeared normal could these amounts of Ca and Mg be considered in the category of luxury consumption? The effect of an increase in K in decreasing the Ca-Mg content and the independent seasonal migration of potassium

all provide many complications for any foliar diagnoses based on their inter-relationships.

When precaution is taken to sample the trees in early summer, leaves of non-bearing prune trees do reflect the K content of the soil. This is demonstrated by the data in Fig. 2 in which the chemical data for the individual tree and the soil in which it is grown are presented. The trees were planted in 1932 and the leaf data are based on the averages of two samplings made in June and July in 1936. The land had received differential fertilizer treatments some 2 to 5 years previous to planting, and the replaceable potassium was determined when the trees were 2 to 3 years old. Many studies have been made on this soil and no downward movement of applied potassium has been noted over a 10 year period so that the K content is a fixed one and need not be re-determined from season to season. This high fixing power had been ascertained earlier and the K salts were therefore injected into this soil. Neubauer studies indicate that the soil in question does not supply any non-replaceable K so that the replaceable data reported here are a direct measure of the potassium available to the tree. This is not true of all California orchard soils (2).

The data in Fig. 2 seem to indicate that a maximum K content of the leaf is reached when the replaceable (or Neubauer) K in the 0- to

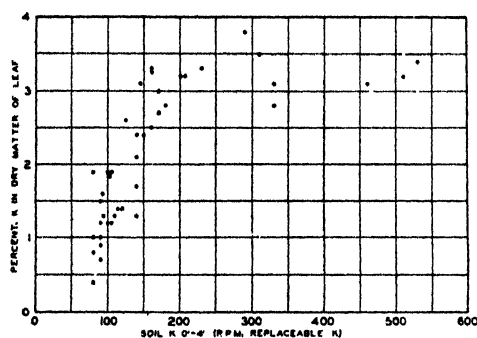


FIG. 2. Analyses of leaves of individual trees and the soil in which they are grown, Agen (French) prune 4th leaf, Canfield orchard. Leaf values do not increase after the available K in the soil reaches 200 ppm.

4 foot depth is raised to 200 ppm. Additional application does not produce any appreciable increase. The question of distribution of K in the soil is an important one. Had the K been applied to the surface instead of being injected it is probable that the leaf value would not be the same. This factor of "positional availability" has been shown to be important in the case of prune trees in the field, but sufficient critical data are not at hand to indicate the relative values of various depths. There is a suggestion in a few instances that increasing the K content in the 0 to 2 foot depth has raised the K content in these 4-year-old trees as effectively as a deeper distribution. Differences might be expected with increased age and deeper root penetration.

A study has been made of the relationship between the K content of the leaf and the appearance of the deficiency symptoms. In general, there is no indication of a lack of K during the first 2 to 3 years in the orchard. Only from leaf analyses can one ascertain at this time which trees are growing in the high and low K plots. Bearing distinctly in-

tensifies the symptoms which consist of a chlorosis and scorch of the foliage. These also become more distinct later in the season but may often be noted in early June in the most deficient areas.

The relationship between K content of leaf and evidence of deficiency symptoms are listed in Table IV. No single value appears to be critical.

TABLE IV—THE K CONTENT OF THE LEAF AND THE PER CENT OF TREES SHOWING K DEFICIENCY SYMPTOMS (CANFIELD 4TH LEAF)

	Per Cent K in Dry Leaf Matter				
	>2.0	1.5 to 1.9	1.0 to 1.4	0.5 to 0.9	<0.5
Total number of trees . . . . .	61	14	28	16	9
Number of trees showing deficiency symptoms . . . . .	1	4	12	12	9
Per cent of trees showing deficiency symptoms . . . . .	1.6	28.6	42.9	75.2	100.0

Only one tree in a total of 61 examined showed symptoms with a leaf K content above 2.0 per cent. In the group having a K content of 1.5 to 1.9 per cent (inclusive), four out of the total of 14 showed some chlorosis or scorch. In the next bracket 1.0 to 1.4 per cent (inclusive), 12 out of 28 showed distinct evidence of deficiency. In the 0.5 to 0.9 per cent (inclusive), K class, 12 out of 16 were sick and all nine trees with a K content less than 0.5 per cent showed very definite symptoms. A study of the healthy trees in the low K groups has so far failed to reveal the factors responsible for their singular behavior. K analyses of the soil in which they are growing have been made and confirm the leaf data with regard to their low K level. It is improbable that they will continue to be symptomless in the following years.

*Bearing Trees:*—Young non-bearing trees in general reflect in their leaf analyses, the available K content of the soil and exhibit symptoms in accordance with such data. Bearing trees, however, do not furnish such conformitory data. The effect of the crop on reducing the K content of the leaf is an important one as can be readily demonstrated by defruiting trees in early summer and comparing their leaf analyses with adjacent trees not so treated. This has been repeatedly demonstrated and data in Table V are typical. Since the amount of crop is a

TABLE V—THE EFFECT OF CROP ON THE PER CENT K CONTENT OF THE LEAF (WOODWARD ORCHARD 1933)

	May 11	June 7	July 6	August 15	September 19
Defruited . . . . .	1.6	2.0	2.3	2.4	2.0
Bearing . . . . .	1.6	1.8	1.7	1.7	1.5

variable which changes with season and orchard, the leaf analyses of bearing trees do not serve to evaluate their K status. Limited data suggest that it is possible to produce K differences between the halves of a single tree by defruiting one-half and allowing the other to bear heavily. The mobility of potassium is again emphasized by these studies. The data suggest that potassium moves from the leaf into the fruit. The possibility that heavy fruiting may reduce root activity and K absorption (if one assumes a cross-over of carbohydrates in the



roots), does not seem so likely from the "half-tree" evidence. Still, analyses of leaves from heavy bearing trees growing in a soil which is naturally well supplied with K do not show lower minimal K values than do similar trees which have received a luxury application of K salts. This in turn suggests a reduced root activity concomitant with heavy yields and an inability of the roots to absorb the K and reflect such soil differences in the composition of the leaf.

An examination of the leaf K content of individual bearing trees over a number of seasons has revealed distinct K levels which, however, varied in their rank from season to season. Thus a tree which distinctly exhibits a superior K status in one season may, during the following year, be at a constantly low K level. Such transient K levels indicate the importance of factors other than the soil in determining the leaf K content of bearing trees and preclude the establishment of critical values for a diagnosis of K deficiency in bearing trees.

#### THE LEAF POTASSIUM CONTENT OF VARIOUS FRUIT SPECIES

Leaf samples have been taken from an experimental orchard in which the following species are planted in adjacent rows in orchard form: Sweet cherry — *Prunus avium*, var. Bing; European plum —

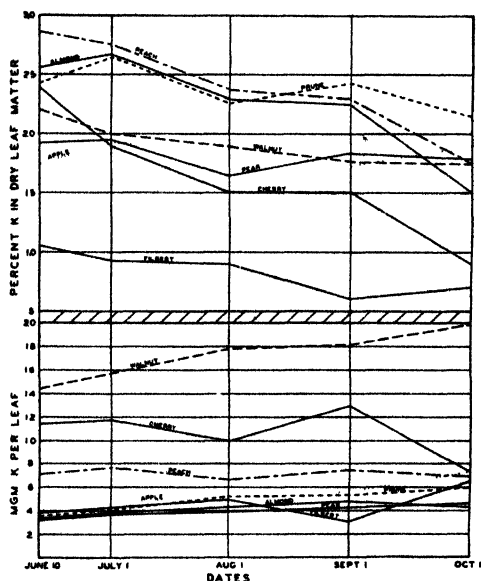


FIG. 3. The K content of the leaf of various fruit and nut trees when grown in the same horticultural environment. The higher K requirement of the prune as compared with the almond or peach cannot be ascertained from their leaf analyses.

*Prunus domestica*, var. Agen; peach—*Amygdalus persica*, var. Elberta; pear—*Pyrus communis*, var. Old Home; apple—*Malus sylvestris*, var. Red Delicious; English walnut—*Juglans regia*, var. Franquette; filbert — *Corylus avellana*, var. Barcelona.

As noted earlier, the potassium content of the leaf at any one time may vary within an orchard with K variations which exist in the soil so that comparisons such as the above should be made with trees not too far removed from each other in order to distinguish K contents characteristic of the species. This is minimized in this planting, and it is assumed that the differences are therefore more significant than

comparisons of these trees in different orchards. The trees are planted 20 feet apart, so that the greatest distance between any comparison is 160 feet. The sequence of planting is as follows: filbert, walnut, apple,

pear, peach, almond, prune, cherry. The leaf data presented in Fig. 3 are from non-bearing trees in their third leaf.

There appears to be a general trend towards a lower per cent K as the season advances. The peach, prune and almond show a closely related K percentage in the leaf dry matter and are distinctly higher than the other fruits when comparisons are made on the above basis. The filbert is characteristically low, while the walnut, cherry, pear and apple occupy an intermediary position.

When comparisons are made on the absolute basis, namely, milligrams per leaf, the relationships are quite different. There is no trend toward a lowered K as the season advances. This undoubtedly occurs later than October 1, the date of the last sampling. With the exception of the walnut and possibly the cherry, the amount of K in the leaf remains strikingly constant from early June to October 1 in all species, and the order, as might be expected from the great variation of leaf sizes in the comparison, is markedly different from that based on the percentage composition. That data such as these do not contribute to a study of the relative potassium requirements of the various species, is indicated by other studies which point to a higher K requirement for the prune than for the almond or peach. Almonds and peaches may be planted successfully on low K soils in which prune trees show severe leaf scorch. There appears to be no clue to this situation from the above data.

#### COMPARISON OF THORNTON TEST AND STANDARD LEAF ANALYSES

From data already discussed, it is evident that the potassium content of fruit tree leaves is quite variable and many individual analyses are necessary in order to arrive at dependable conclusions. Any shortening of time and effort in obtaining these analyses would certainly be welcome. The rapid chemical method devised by Thornton (1) was tested and the comparison of this and the standard Lindo-Gladding method on 156 leaf samples is presented in Fig. 4.

The Thornton method was modified as follows: 20 to 30 leaves from each tree were taken to the laboratory. At the same time 100 leaves were selected for the standard analyses. The samples were placed in cold storage and removed as needed. An average of 15 petioles was sectioned and 0.25 grams (measured by fixed volume) was used. The test was run in duplicate. The  $\text{NaNO}_2$  solution was boiled previous to adding the

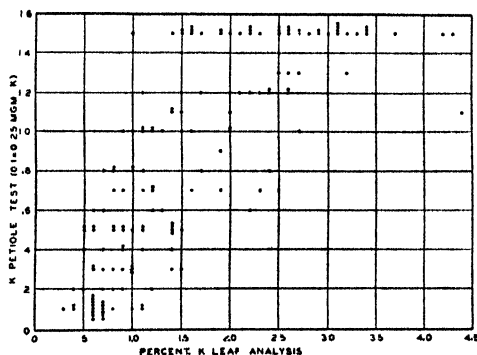


FIG. 4. The relationship between the rapid petiole test for K and standard K leaf analyses (Lindo-Gladding method). The petiole data indicate a range of values which is too wide for the application of this rapid tissue test to potassium studies.

cobalt reagent. This eliminated foaming which previously had presented great difficulty. Standards containing from 0.25 to 3.75 milligrams of K were used for comparison.

While there is some agreement, the scatter of values in Fig. 4 is greater than generally desired. Thus there appears to be in any one Thornton value a range of 1.5 per cent as measured by the standard method which in our work is too wide to be of much use in our potassium studies.

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## Response of Fruit Trees Near The Dalles, Oregon, to Applications of Boron and Zinc<sup>1</sup>

By C. E. SCHUSTER, *U. S. Department of Agriculture*, and O. T. McWHORTER, and R. E. STEPHENSON, *Oregon State College, Corvallis, Ore.*

IN the vicinity of The Dalles, Oregon, which is east of the Cascade Mountains, fruit trees in certain orchards have for years shown a dwarfed, chlorotic condition of the leaves. Affected trees produce weak shoot growth, at times having short or very short internodes so that pronounced bunching or rosetting of the leaves occurs in extreme cases. The trouble may occur on young trees the first year after planting or on old trees after years of satisfactory growth and fruiting. Cherries, peaches, apricots, prunes, apples and pears are affected, but since most of the orchards are of cherries the trouble is especially noticeable on cherry trees. The disorder has locally been known as "little leaf" or "little leaf condition" as some thought it was not the same disease as little leaf in other parts of the country. The soils in this district are quite generally deep and near neutral to slightly alkaline in reaction. The low rainfall averaging 18 inches per year permits a minimum of cover crop growth unless irrigation is practiced which has been done on only a small acreage. The orchards generally are clean cultivated and only a small amount of organic matter has been returned to the soil. Furthermore, some erosion has occurred which has also reduced the fertility.

In 1936, McWhorter (1) reported that zinc sulphate applied as a spray, by injection, or by driving zinc tacks into trees affected with little leaf, consistently improved their condition. Spraying with zinc sulphate was the simplest and most effective way of applying the zinc. Commercial zinc sulphate was used except for one of the early trials when a chemically pure product was substituted. Since McWhorter found that the recovery of diseased trees was not as good with the pure zinc sulphate as with commercial products, the latter has been used in all subsequent trials.

Soil samples from the orchards at The Dalles were made at intervals of 1 foot to a depth of 10 feet. Sunflower plants grown in the greenhouse on these soil samples developed boron deficiency symptoms except occasionally those grown in the samples taken from the surface foot of soil failed to develop such symptoms.

The terminal buds of the sunflower plants were killed or failed to develop when grown on soil samples taken from certain levels below the surface foot, unless additional boron was supplied. The sunflower plants grown on soil samples taken from the surface foot of soil in some cases developed only minor boron deficiency symptoms, indicat-

<sup>1</sup>This report of an investigation conducted jointly by the U. S. Bureau of Plant Industry, the Oregon Federal Cooperative Extension Service and the Oregon Agricultural Experiment Station is published as Technical Paper No. 304 with the approval of the director of the Experiment Station.

ing that even the surface soil did not always contain sufficient boron for normal sunflower growth.

Following these results with sunflowers, samples of the zinc sulfate used in spraying diseased trees at The Dalles were analyzed for the boron content at the Rubidoux Laboratory of the United States Department of Agriculture at Riverside, California. The commercial zinc sulfate was found to contain 15 parts per million of boron, while the chemically pure product showed only a trace of boron. These results led to a suspicion that boron may have been a factor in improving the "little leaf" condition of the diseased trees.

On May 18, 1937, a few small cherry trees that were seriously affected with little leaf were sprayed with commercial zinc sulfate or boric acid solution or the two in combination. The diseased trees sprayed were in the last stages of decline, as they bore only a few normal leaves. Most of the leaves were just protruding from the bud and many were dying; furthermore, many dead shoots were present. Healthy trees bore leaves of full size and normal appearance. Zinc sulfate was used at the rate of 12 pounds to 50 gallons of water and the boric acid was a 4 per cent solution. When both solutions were applied to the same tree, successive sprayings were made of the separate materials. Still other trees having 50 to 75 per cent of "little leaf" were sprayed with 1 and 2 per cent boric acid solutions and also with varying concentrations of zinc sulfate.

On May 26, 1937, 8 days after treatment, improvement in the diseased condition could be noted. The trees that had received either boron or zinc sulfate had made a good recovery. Two weeks later the trees sprayed with zinc sulfate solution alone had a better appearance than those sprayed with boron alone. The improvement in the diseased condition continued on the new growth as the season advanced. The new growth of the trees sprayed with boron solutions produced leaves having varying degrees of little leaf, while the old or first leaves formed remained in good condition. Trees sprayed with both zinc sulfate and boric acid solution showed complete recovery on both the old and the new leaves on the new shoots. Later in the season a large part of the first leaves sprayed with both materials were shed so that the foliage remaining was largely on current year's shoots. The reaction of the leaves to boron solution alone was essentially the same whether 1 per cent or a 4 per cent boric acid solution was used as the spray.

On June 28, 1937, diseased cherry, peach, and apricot trees were sprayed with a 1 per cent solution of boric acid, since a 4 per cent solution with zinc sulfate had caused some defoliation in the earlier work. The portion of the trees not affected by little leaf were actively producing new shoots and leaves. Chlorotic leaves which were coated with boric acid solution were generally restored to a normal color but the new leaves produced after the solution was applied were invariably chlorotic. The leaves on new shoots produced after spraying with zinc sulfate solution were as much improved in appearance as the old leaves which had been covered with the spray. Still greater improvement resulted in the condition of the diseased trees when both zinc sulfate

and boron solutions were applied as compared to those receiving only a heavy application of a zinc sulfate solution.

Observations on previous treatments were continued during the spring of 1938. As soon as the buds opened, leaves on all trees treated in 1937 showed improvement in color and size over the initial appearance in 1937. On trees treated with boric acid alone, in 1937, the first leaves of 1938 held their improved color while the leaves on new shoots were likely to be chlorotic. On trees treated with zinc sulfate in 1937, the first leaves in 1938 gradually darkened in color and the leaves on the new shoots took on some improved appearance, although more or less chlorosis might be present. When both materials were applied in 1937 to the same tree the foliage and shoot growth in 1938 were restored to normal or near normal condition. Thus, neither boron nor zinc alone proved a complete cure for the trouble.

The texture of the leaves of 1938 was influenced by the material applied in 1937. Trees treated with boron alone in 1937 were lighter in color a few weeks after leafing out in 1938 than were zinc treated trees. A peach tree, one half sprayed with zinc sulfate and one half with boric acid solution in 1937 showed marked difference in response to the treatments. The half treated with zinc sulfate was darker green in 1938 and the leaves were thicker than normal and brittle to the touch, with a pronounced wrinkling. The half of the tree treated with boric acid produced foliage lighter in color, thinner than normal, soft and pliable. By fall all the leaves on both halves of the tree were chlorotic while adjoining trees treated with both zinc sulfate and boric acid were normal in appearance.

The results of 1937, indicate that of the two minor elements involved zinc is of major importance and boron is of secondary importance, while both are necessary for complete recovery. The treatments and observations were continued through 1938. Records taken in October 1938 showed essentially the same results as those obtained in the fall of 1937. Zinc sulfate combined with 1 or 2 per cent boric acid solution produced the best foliage with practically 100 per cent recovery from little leaf. In some cases the leaf drop was heavy but no greater than the average of trees that had not been sprayed. Apparently neither little leaf disorder nor the spray treatments were responsible for the shedding of the leaves.

Two seasons' study indicate that the trees affected with "little leaf" condition can be restored to normal appearance and growth by spraying with solutions of boric acid and zinc sulfate. More study will be needed to determine whether the recovery is permanent.

#### ACKNOWLEDGMENT

Grateful acknowledgment is due Wray Lawrence, county agent, and Grant Perry, assistant county agent, for their helpful assistance in applying the sprays and taking the data.

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## Some Apple Tree Stock Relationships Seen in New England after 1938 Hurricane<sup>1</sup>

By F. B. LINCOLN, *University of Maryland, College Park, Md.*

A hurricane in New England on September 21, 1938, blew hundreds of thousands of apple trees out of position and many were almost completely uprooted. The two principal varieties, McIntosh and Baldwin, were in an excellent state of vigor and carried good crops of fruit. All of the trees observed were growing in sod which generally was luxuriant. Just prior to the wind the soil had been supersaturated with 10 or more inches of rain. This almost fluid condition of the soil allowed the trees to change position or to be completely uprooted by the repeated gusts of wind. The damage in some cases was accomplished in a few minutes and in other locations trees continued to go over for 2 hours or the duration of the storm. Besides the loss of the fruit crop there was much limb injury to some varieties but in this study only uprooting will be considered. Everyone was astonished at the shallowness of the apple roots. In many instances after the storm, the roots were out of the soil and it was only with close scrutiny that it could be determined where they had come out of the sod. The tree damage was very much related to exposure, being most severe on slopes facing the wind. In many instances trees on elevated level ground above the slope were not damaged.

The uprooting of these trees can be considered from several points of view, the one chosen for this study is the scion-stock relation. It appeared to be a perfect opportunity to relate the findings on root firmness to several of the scion-stock hypotheses. Three current ideas will be considered: (a) The crown of the tree has a dominating influence on the properties and characteristics of the stock roots; (b) the trunk of the tree is the part which gives specific properties and characteristics to the stock roots; and (c) erect growing trees have deep penetrating root systems. The scion may influence the roots in many respects contributing to their firmness in the soil; there is the ratio of their weight to that of the top, then the number of laterals, their size, arrangement, rigidity, declivity and fragility. The secondary laterals may contribute by their frequency, angle of divergence, length, and fragility. With a young tree the small roots and fiber will aid in its ability to cling to the soil. It will be assumed that the stock was French crab seedlings, and no one will venture a guess as to the amount of scion rooting that may have occurred. There were at least six orchards on dwarf stocks within the area of severe damage.

Nearly a month was spent in observing uprooted trees in Connecticut and Massachusetts, and since then much information has been gained from experience with discarded trees which are being pulled out by tractors. It is expected that the latter trees will give evidence clarifying the different abilities to withstand the storm shown by cer-

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<sup>1</sup>Scientific Contribution No. 492, Department of Horticulture, Maryland Agricultural Experiment Station.

tain varieties in New England. They will also increase the records of root characteristics associated with varieties. So far in this study about 400 photographs have been made of roots of mature trees. No one knows why certain trees and certain varieties responded to the storm as they did. For this reason the study has been extended into Maryland and Virginia where discarded trees are being removed by tractors. These trees exhibit great differences in ease of extraction, and in certain parts of orchards the trees break off rather than be extracted, showing a firmer soil attachment.

A common statement heard in the storm devastated region of New England was, "My Macs are all down." Because of the prominence of McIntosh and the inability of the trees to withstand the storm the study soon began to revolve about this variety and its use as a standard of comparison. Such varieties akin to McIntosh as Cortland, Macoun, Milton, and Early McIntosh fell before the wind as readily as did McIntosh. In one orchard 50-year-old Fameuse trees remained standing while the adjacent rows of McIntosh trees were mostly down. The following groupings of trees as to their ability to grip the soil are based on observations made where they stood close to McIntosh. The varieties making trees which seem less stable than McIntosh are: Red Astrachan, Tompkins King, Yellow Transparent, and Gravenstein. Varieties which, though not entirely resistant, were more root-firm than McIntosh, are: Baldwin, Ben Davis, and Delicious. Varieties whose trees were very stable and showed no uprooting, include: Duchess, Fameuse, Fall Pippin, Golden Delicious, Pound Sweet, R. I. Greening, Northern Spy, Steele's Red, Sutton, Wealthy, and Williams. The uprooting of apple trees was closely related to varieties.

The second hypothesis to be tested in this study is that the trunk of the tree is the part which gives specific properties to the stock roots. Trees top worked to McIntosh will be a case for consideration. This variety was found top worked, usually on the limbs, on Baldwin, Ben Davis, Black Twig, Fall Pippin, Limbertwig, Steele's Red, and Wolf River, and in every case they were uprooted. The influence of the trunk on the root system was not sufficient to keep these top worked trees from blowing down. Most of them were stable in cases where they carried their own tops. It appears that the McIntosh crown has more influence than the trunk variety on the makeup of the root system. One McIntosh top worked on Maiden Blush and another on Stark were found, both standing. This may be insignificant but recently it was observed that Maiden Blush trees had a deep root development. These top worked trees were few and usually not enough of their roots were exposed to indicate whether they resembled those under standard McIntosh trees. It is likely that they did not, for the gross root structure had been developed before the top working was done.

Two instances of self-rooted McIntosh trees were found in the storm area. At Storrs, Connecticut, one such tree stood while the trees, of a different variety, on either side of it, had blown over. At Amherst, Massachusetts, are a dozen or so self-rooted McIntosh trees which were severely damaged by the storm. Dr. Shaw states that these trees



are standing in a very thin soil and that some were not symmetrically rooted at the time they were planted.

Much interest is likely to develop in the ability of dwarf trees to stand this storm, for they are supposed to be unstable in strong wind. In one Connecticut orchard of standard McIntosh interplanted with dwarfs, the trees were not badly damaged but the standards stood better than the dwarfs. In another Connecticut orchard of dwarf McIntosh, the trees on Doucin stood the storm while those on Paradise stock went over, as did many of the standard McIntosh. A report from a dwarf orchard of four varieties in New Hampshire states that only three trees were down. In a dwarf orchard of mixed varieties about half of the trees were down while adjacent standard McIntosh trees suffered badly. At Amherst, McIntosh on East Malling stocks X, XIII, and XVI stood better than standard trees. Those on stocks I and XII were more exposed to the wind and did not stand as well. It may be said that dwarf McIntosh trees in general stood about as well as standard trees.

An appreciable number of standard trees were found broken at the graft union, perhaps to the extent of 1 or 2 per cent of all blown down trees examined. The Gravenstein variety showed this occurrence in greatest proportion. Either this defect or brittleness of the roots, chiefly contributed to this lack of resistance, for rarely were any roots exposed on the damaged trees. From the exterior these broken unions did not show irregular development, but on the inside it was clearly evident that the wood fibers terminated at the graft union, presenting a structural weakness. A similar percentage of tractor-pulled trees has been found to have broken at the union. In some cases it appears that in the early life of the trees the wood fibers extended across the region of the unions, but as the trees matured the unions became well marked regions with the fibers not extending across them, and with greater age bark was deposited between the new wood of the scion and stock.

The explanation commonly given in New England for certain varieties being uprooted more than others is that they were vigorous, and had large leaves, and their compact crowns offered more resistance to the wind. It appears that the ratio of roots to top may have been a factor in these cases, for perhaps the tops were out of proportion to the roots. To evaluate further the hypothesis that the crown of the tree determines the specific properties of its roots, we may refer to Delicious, Duchess, and Wealthy, which were quite stable in the storm. They are likewise very resistant to extraction by tractors; the trunk frequently breaking without lifting the roots. The root system of Delicious (Fig. 4) is coarse and inclined to be deep. The roots of Duchess and Wealthy (Fig. 4) besides having good lateral development have many vertical roots under the trunk. The author has gained the impression from seeing many tractor-lifted Wealthy trees that they have a large proportion of roots to top.

Some root pictures (Figs. 1, 2, 3, and 4) are presented here for consideration and comparison; the first two are wind uprooted and the last are firm rooted-tractor extracted. Since it was possible to observe only uprooted systems, it is not possible at this time to say

that these are the most probable types of the expression of the scion in seedling roots. Only further investigation and the collaboration of other workers will make this possible. The present undertaking is only a very small beginning. The pictures presented in Figs. 1, 2, 3, and 4 are of wind exposed roots from New England and of tractor extracted roots of Maryland and Virginia.

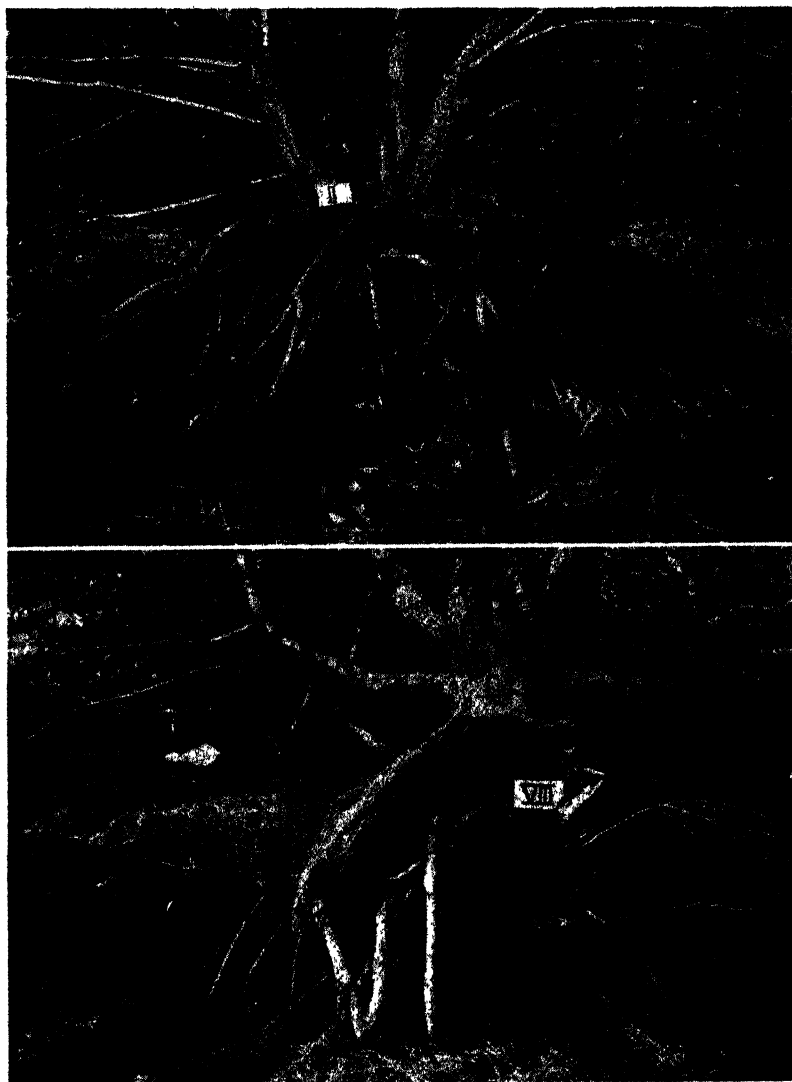


FIG. 1. Upper : McIntosh. Lower : Baldwin (both exposed by wind).

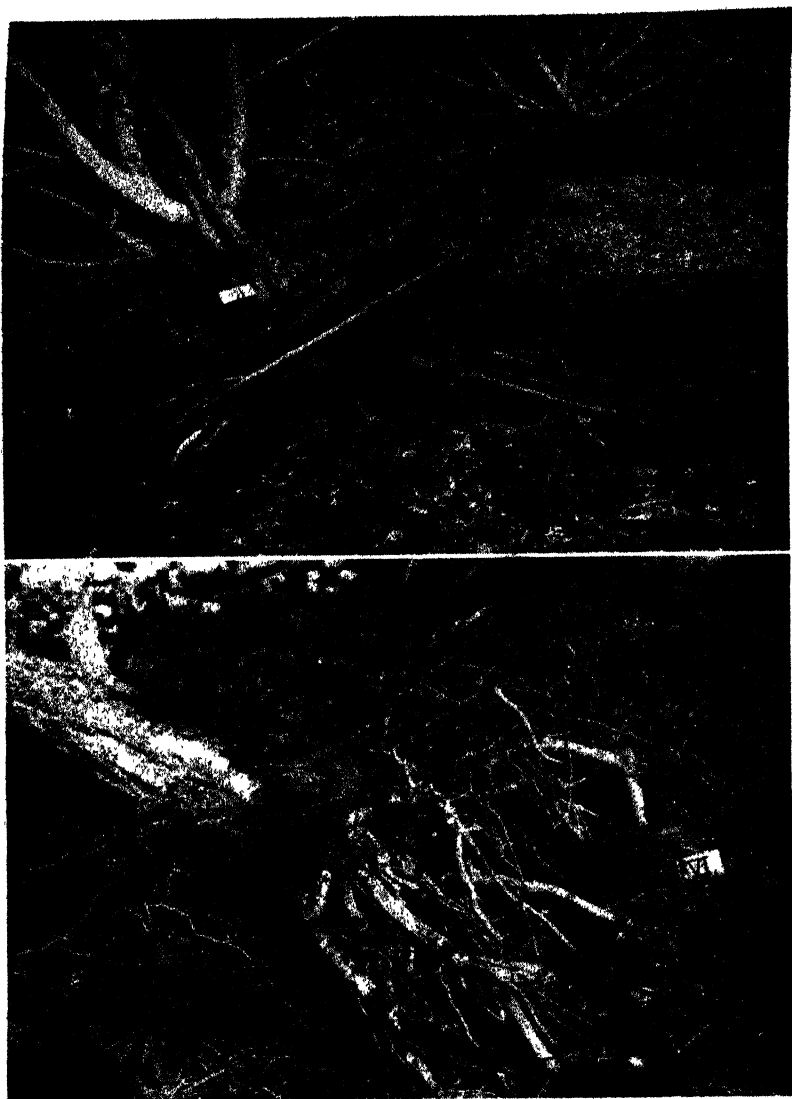


FIG. 2. Upper : Red Astrachan. Lower : Ben Davis (both exposed by wind).

A striking observation is that the roots under Delicious, Duchess, Wealthy and Maiden Blush tops when exposed by tractor extraction in Maryland and Virginia exhibit root systems of greater depth than any of the wind lifted trees of other varieties in New England. Perhaps this explains why the first three kinds were found to be stable to the wind. The forms of deep rooting may be of three types: (a) lateral

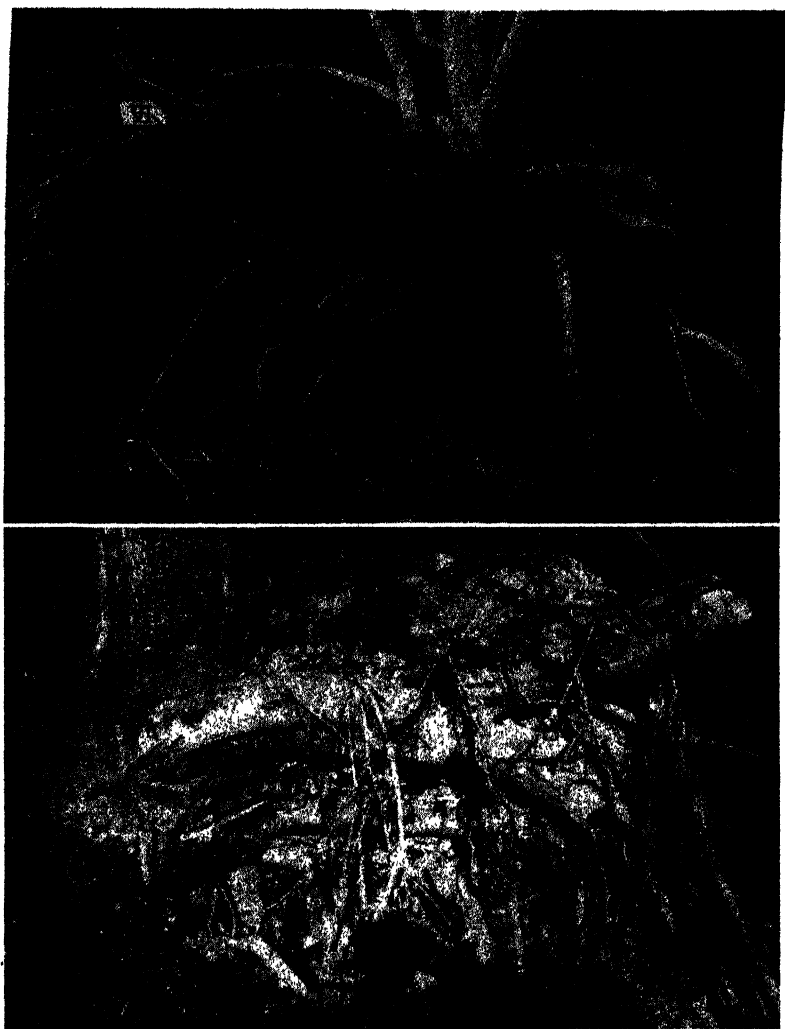


FIG. 3. Upper: Yellow Transparent. Lower: Gravenstein (both exposed by wind).

roots having a great inclination from the horizontal, (b) vertical roots descending from the more or less horizontal laterals, (c) vertical roots descending from the center of the root system or sub-central development. Ben Davis, Wealthy, and Duchess have a strong development of roots below the laterals in the center of the root system, while Baldwin, Yellow Transparent, Gravenstein, and Delicious are barren of roots in this position. McIntosh is just as free of this sub-central development but this fact is not shown in the picture, being obscured

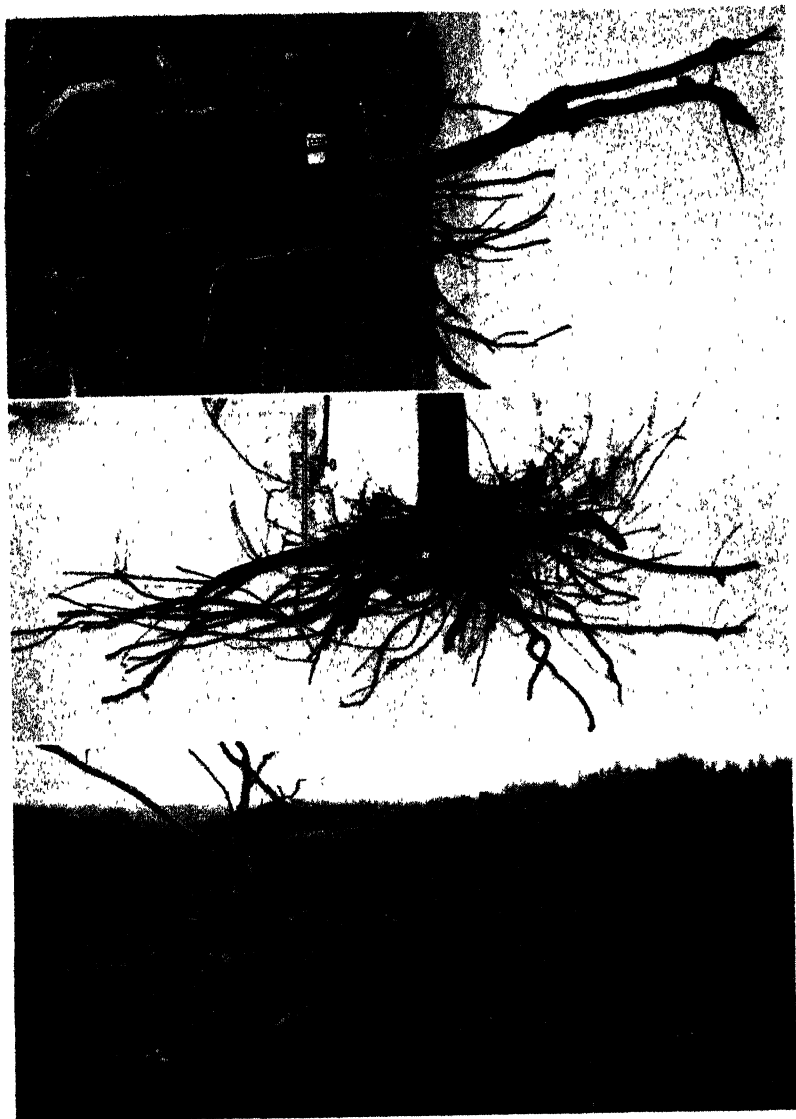


FIG. 4. Upper: Wealthy. Middle: Delicious. Lower: Duchess (all tractor extracted).

by a large number of pliable laterals. The roots under McIntosh were always smaller and more pliable than those under Baldwin. These tendencies in development may be varietal expressions of either the scion or the root or of both. The magnitude of the development may be

a function of age and soil environment. In New England among the uprooted trees there were no examples of a tendency to deep rooting, except perhaps with Ben Davis and Yellow Transparent. This surface rooting may be characteristic of the crown varieties of the wind damaged trees. It is possible that roots growing under a dense sod with adequate moisture and surface applied fertilizers, find conditions most favorable for their development near the upper surface of the soil, but this should not prohibit the expression of varietal tendencies from appearing in other positions of the system and at different levels. The shallow rooting of uprooted trees in New England may be explained by the presence of an impervious hardpan below a thin surface soil. Two orchards were visited in which the holes had been blasted previous to planting, but these trees were no more stable to the wind than were those in orchards where no blasting had been done. Work is now in progress on the extraction of some of these varieties growing in deeper soils, to determine their rooting habits under such conditions.

This work was undertaken to relate the root-firmness of varieties to some scion-stocks hypothesis. There seems to be nothing contrary to the premise that the crown of the tree has a dominating influence on the stock roots, if it is assumed that the roots were similar at the time of propagating, for the uprooting of trees was very definitely related to scion varieties. The second hypothesis; i.e., that the trunk of the tree is the part which gives specific properties to the stock roots, was not well supported, inasmuch as McIntosh, when top worked on other varieties which in themselves were stable to the wind, caused the trees to become unstable. The third hypothesis, that erect-growing trees have deeply penetrating root systems may or may not be supported by the results. It may be considered reasonable that deep rooted trees would show greater root firmness than shallow rooted trees. Field observations showed that the two erect growing varieties Northern Spy and Sutton were root-firm in the wind while two others, Macoun and Yellow Transparent, were not. The benefits of deep rooting, if it was present, might have been offset by fragility of roots. The low-headed R. I. Greening was extremely stable in the storm.

# Observations on Mazzard and Mahaleb Seedlings Bench Grafted to Varieties of Sweet and Sour Cherries<sup>1</sup>

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THE nurseryman growing Mazzard and Mahaleb seedlings is at times confronted with seedlings which are too large to be used as lining-out stock for budding (2). Such oversized seedlings should furnish valuable plant material in cases where a tree trunk is desired other than the budded variety. This at once presents the problem, whether it is possible to bench graft Mazzard and Mahaleb seedlings successfully. The purpose of this paper is to present observations on this problem.

## MATERIALS AND METHODS

Mazzard (*Prunus avium* L.) and Mahaleb (*P. Mahaleb* L.) seedlings which measured 9 to 10 millimeters in diameter at 5 inches above the crown were used. These seedlings were from 30 to 36 inches tall. They had been grown by a commercial nursery and were dug in the fall of 1936 and stored in a nursery cellar until the end of February.

At the beginning of March all were cut back to a uniform height of 26 inches, measured from the crown. Any lateral branches present were removed at the same time. Twenty-five seedlings each were grafted, at the height to which they were cut back, to the Giant and Early Rivers sweet cherries and to the Montmorency sour cherry. The scions used had been cut from orchard trees in late December and stored in sand in the nursery cellar. The tongue graft was used throughout, each scion being from 5 to 6 inches long with at least four buds. Particular care was taken that stock and scion were of similar diameter and that they matched well. Grafting tape was employed for tying the grafts. Tied in bundles, the completed grafts were trenched in sand in the nursery cellar until planting time, and while still in storage the grafts had opportunity to callus.

Planting in the nursery row was done on May 3, with a favorable growing season following. As new growth started, all lateral shoot growth appearing below the graft union, was repeatedly pinched back to favor growth of the scion variety and still bring about the necessary diameter increase of the trunk. After shoot growth had ceased in late summer, the largest lateral shoots of the stock were entirely removed.

## OBSERVATIONS

Any successful grafting operation and particularly bench grafting cherry varieties to Mazzard and Mahaleb seedlings, as has been described, depends on several factors. Of these, properly matured and stored scion wood, faultless grafting operations, compatibility of stock and scion, and the root system of the grafting stock, are the most

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<sup>1</sup>Journal Article No. 320, New York State Agricultural Experiment Station.

important. The root system is of importance because it will have an effect on the way the grafted seedlings will stand transplanting and so may decidedly influence the total stand of salable trees obtained. To be sure, there is a distinct difference in the root systems of Mazzard and Mahaleb seedlings. Mazzard seedlings produce a persistent tap root and numerous smaller laterals, which make the whole root system very fibrous. Mahaleb seedlings, on the other hand, have stringy roots and on 1-year-old seedlings fibrous roots are, with rare exceptions, totally absent. It is thus quite possible that the Mazzard seedlings will establish themselves, on transplanting, more rapidly than the Mahaleb seedlings of the same size. As may be seen from Table I, all grafted Mazzard seedlings survived transplanting and grew vigorously in the nursery row, but the Mahaleb seedlings, handled in exactly the same manner, behaved quite differently. Only 76, 88, and 92 per cent, respectively, survived transplanting and grew vigorously. The prospective final stand of grafts on the Mahaleb stock was thus already at a disadvantage.

TABLE I—OBSERVATIONS ON MAZZARD AND MAHALEB SEEDLINGS BENCH GRAFTED TO VARIETIES OF SWEET AND SOUR CHERRIES

Variety	Number of Seedlings Grafted	At End of First Growing Season		Mean Trunk Diameter (Mm.) of Salable Trees After 2 Growing Seasons
		Per Cent of Seedlings Which Grew	Per Cent Salable Grafted Trees	
Mazzard Seedlings				
Giant	26	100	84.82	17.50
Early Rivers	25	100	60.00	19.31
Montmorency	25	100	88.90	18.40
Mahaleb Seedlings				
Giant	25	76	32.00	14.68
Early Rivers	25	88	9.09	18.36
Montmorency	25	92	80.00	16.13

So far as the total number of successful grafts is concerned, with the sweet varieties, Giant and Early Rivers on Mazzard, a considerably higher percentage of salable trees was obtained than with the same varieties on Mahaleb. Eighty-five per cent of Giant on Mazzard, and 60 per cent of Early Rivers on Mazzard, were salable trees, while the same varieties grafted on Mahaleb gave stands of only 32 and 9 per cent, respectively. Although Mahaleb seedlings proved unsatisfactory, as grafting stock for sweet cherries, they gave very good results when the sour cherry, Montmorency, was grafted on them. As is shown in Table I, the percentage stand of salable trees with the variety Montmorency, was 89 per cent on Mazzard and 80 per cent on Mahaleb. Taking into consideration that the Mahaleb seedlings had a root system which was not as good as that of the Mazzard seedlings, and on transplanting to the nursery did not grow as well, there is still too great difference in the stand as far as the two sweet varieties, Giant and Early Rivers, are concerned. Since all grafting operations were carried out by the author and identical scion wood and storage condi-



tions were provided for both Mazzard and Mahaleb, the variations in stand which occurred with the two stocks lead to the belief that the sweet cherry varieties used are to various degrees less compatible when whip grafted to a Mahaleb than to a Mazzard seedling trunk.

### CONCLUSION

The results obtained show that the sweet as well as the sour cherry can, during the dormant season, be bench grafted successfully on Mazzard seedlings which are too large for subsequent budding. Such practice can open an entirely new field in that it not only shortens the time to produce a cherry tree by 1 year, but also makes possible the use of seedlings which, otherwise, would be useless and to graft known varieties to seedling trunks which might perhaps have particular merits in regard to hardiness and disease resistance.

Slight variations in the results with different varieties may occur, but provided the scion material, as well as the stock, is in proper condition, there should be no serious difficulty in raising cherry trees by bench grafting, which can be transplanted to the orchard at the end of the first or second growing season. The results with Mahaleb seedlings lead to the conclusion that sour cherries thrive better on Mahaleb than do sweet varieties (1), and that various degrees of incompatibility may exist between the Mahaleb trunk and the scion variety.

Since many nurserymen believe that the Mazzard root stock budded in the nursery row is more likely to be injured by winter cold than budded Mahaleb stock (3), it seems to be of importance to give further trial to propagation methods such as described.

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# The Behavior of Malling Apple Rootstocks in the Nursery<sup>1</sup>

By H. B. TUKEY and K. D. BRASE, *N. Y. State Agricultural Experiment Station, Geneva, N. Y.*

**A**LTHOUGH there is wide interest in the Malling rootstocks in the United States at the present time, there is a dearth of information upon their adaptability and performance. Further, because of the Federal embargo against the importation of rootstocks for use as understocks, attention is directed at the development of an American supply. Accordingly, the performance of these rootstocks in stool block and in nursery becomes of particular interest. Although the information which follows is fragmentary and in summary form, it is offered as a progress report of the behavior of these rootstocks in the nursery section of western New York, during an 11-year period from 1928 to 1938, inclusive, and involving the propagation of over a 100,000 rooted plants and 20,000 budded trees.

*Malling I — Broad-Leaved English Paradise (of Rivers):*—English origin by T. Rivers about 1860. Vigorous and tall growing in stool beds with very little branching, makes heavy shoots, best trench layered, blighted in 1938, shoots mature early and can be removed from mother plant in fall, roots easily and well, 18,000 to 25,000 salable plants per acre. No injury from severe winter 1933–34; hardy, 100 per cent survival over 6-year period. Excellent stand as lining-out stock, strong grower. Good stand of buds (87 to 90 per cent). Makes vigorous nursery trees with strong growing varieties; unsuccessful for Wealthy (1).

*Malling II — Doucin:*—Also called “English Paradise” and “Doucín” by best French nurseries. An old stock at least two centuries old. Stiff, erect, wood tough, matures early and has bright yellow leaves in fall when other types are still green. Does not root too easily, best propagated by stooling and left mounded until spring, 17,000 to 22,000 salable plants per acre. No injury from severe winter 1933–34; hardy, 83 per cent survival over 6-year period. Good stand as lining-out stock, good grower. Good stand of buds (82 to 95 per cent). Has flat type root, does not sucker like commercial “Doucín”.

*Malling III — Unnamed:*—At first thought to be “Dutch Doucin”. A common stock, widely distributed in Europe. Has characteristic “holly leaf.” Roots very easily and well, best propagated in stools. No injury from severe winter 1933–34; hardy, 100 per cent survival over 6-year period.

*Malling IV — Holstein Doucin:*—Also called “Dutch Doucin”. Originally identified as *Malus pumila*; common in Holland and Germany. Sturdy clean grower, roots easily, best propagated in stools. Pith badly discolored from severe winter of 1933–34. Hardy, 83 per cent

<sup>1</sup>Journal Article No. 319, of the New York State Agricultural Experiment Station.

survival over 6-year period. Excellent stand as lining-out stock, good grower. Hard to bud in the nursery, does not take buds well. Root system somewhat like Malling II but not so good, trees tending to lean.

*Malling V — Doucin Amélioré:*—Also called "Improved Doucin" in England and "Red Paradise" in Holland and Germany. Common in Europe. Roots easily, best propagated from stools. No injury from severe winter of 1933-34. Hardy, 100 per cent survival over 6-year period.

*Malling VI — Nonsuch Paradise (of Rivers):*—Also called "Rivers' Paradise". Selected by T. Rivers about 1860. Roots easily, best propagated from stools; behaves much like Malling IV. Slight browning in pith and some in xylem from severe winter of 1933-34. Not especially hardy, 33 per cent survival over 6-year period.

*Malling VII — Unnamed:*—Long known in English nurseries, little used. Produces many shoots, which are especially smooth and free from lateral shoots, roots easily and well, produces high proportion of medium size shoots, best propagated from stools. Browning in pith and some in xylem from severe winter of 1933-34. Hardy, 100 per cent survival over 6-year period. Excellent stand as lining-out stock, good grower. Does particularly well on the heavy soils at Geneva.

*Malling VIII — French Paradise:*—Common on the Continent. Weak grower, shy rooting, makes small stocks. Browning in pith and some in xylem from severe winter of 1933-34. Not hardy, 17 per cent survival over 6-year period.

*Malling IX — Jaune de Metz (of Dieudonné):*—Also called "Yellow Metz" and "French Paradise". Chance seedling about 1879. Shoots of medium height and diameter, roots easily and well, propagated without difficulty but requires attention, best propagated from stools, 20,000 to 30,000 salable plants per acre. Excellent stand as lining-out stock, good grower. Roots snap and break easily. Buds well (89 to 93 per cent stand) but best not budded until late August, if budded earlier buds may start same season; rubber and other tying materials girdle stem easily. No injury from severe winter of 1933-34. Only moderately hardy, 50 per cent survival over 6-year period.

*Malling X — Unnamed:*—Doucin U.1 from Späth Nurseries, Berlin. A vigorous grower, but less so than Malling XVI. Roots not so stringy as Malling XII, has many small roots like Malling XIII. Might be thought of as a slightly less vigorous Malling XIII. Pith and xylem badly injured by severe winter of 1933-34. Not especially hardy, 50 per cent survival over 6-year period.

*Malling XI — Unnamed:*—English origin from crab stocks. No report.

*Malling XII — Unnamed:*—English origin from crab stocks. Upright grower, very vigorous, easily separated from Malling XIII by upright habit; roots with difficulty and should not be taken from mother plants until spring. Roots are sparse but tough, quite unlike other types, suggestive of Mahaleb root in shape, downward spreading. Best propagated by trench layering, 8,000 to 12,000 salable plants per acre. Good stand as lining-out stock, good grower. Buds well (86 to

94 per cent stand). Has done well on heavy soils at Geneva. Browning of pith and xylem rays from severe winter of 1933-34. Hardy, 83 per cent survival over 6-year period.

*Malling XIII — Unnamed:*—Doucin U.2 of Späth Nurseries, Berlin. Very vigorous, with spreading laterals. Root system suggestive of Mazzard with heavy roots and many fibers, more shallow than Malling XII. Holds leaves until spring, probably best not removed from mother plant until spring. Roots easily and well and best propagated by trench layering, 20,000 to 25,000 salable plants per acre. Excellent stand as lining-out stock, strong grower. Seems to do well on heavy soils. Takes bud especially well (96 to 99 per cent stand). Showed severe blight in 1938. Slight discoloration from severe winter of 1933-34. Moderately hardy, 50 per cent survival over 6-year period.

*Malling XIV — Unnamed:*—Doucin U.5 of Späth Nurseries, Berlin. No report.

*Malling XV — Unnamed:*—Doucin U.6 of Späth Nurseries, Berlin. Browning in pith and some in xylem following severe winter of 1933-34. Not especially hardy, 33 per cent survival over 6-year period.

*Malling XVI — Unnamed:*—Doucin U.3 of Späth Nurseries, Berlin. Also called Ketziner Ideal. Very vigorous; has dark leather-like leaves with smooth margins at base, starts late in spring but matures early in fall. Roots very slowly, best left on mother plant until spring, 10,000 to 12,000 salable plants per acre. Good stand as lining-out stock, strong grower. Buds especially well (95 to 96 per cent stand of buds). Pith badly injured by severe winter of 1933-34. Hardy, 100 per cent survival over 6-year period.

*General Note:*—Malling II and XVI take a wide assortment of buds equally well; Malling XII and XIII take a less wide assortment; Malling I shows uncongenialities. The more easily rooting types, as I, IX, IV, VII, and XIII, produce the best stands as lining-out stock, whereas the less easily rooting types, as II, XII, and possibly XVI, produce a relatively poorer stand.

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## Influence of the Stocks on the Performance of Certain Apple Varieties<sup>1</sup>

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AN orchard was set out on the University Experiment farm at Kearneysville, West Virginia, in 1933 by the West Virginia Agricultural Experiment Station in cooperation with the United States Department of Agriculture for the purpose of comparing the performance of a number of seedling and clonal apple stocks. It consists of two blocks, one of 2,644 trees (as originally planted) to compare standard stocks chiefly, the other of 252 trees to compare two dwarfing stocks.

The site is on Hagerstown silt loam soil sloping enough for good drainage and is gently rolling in contour. Although there is soil variation, the site and the fertility of the soil compare favorably with the better commercial orchards of the Shenandoah-Cumberland Valley. The orchard has been in alfalfa sod. Nitrogen and fungicidal and insecticidal sprays have been applied uniformly to the trees. In the larger block the deeper and less eroded soil is on the east side, the fertility and depth of surface soil gradually becoming somewhat less toward the west. A few rock outcrops are present, mostly in the western portion. In the smaller block the deeper soil is at the north end of each row and the shallower soil is at the south end.

### STANDARD STOCKS

In the larger block, both seedling and clonal stocks are represented. The seedling stocks of known maternal parentage are Rome Beauty, Wealthy, Jonathan, Delicious, Northern Spy, Grimes Golden, Wine-sap, McIntosh, Tolman, and Fameuse. Seed from some of these varieties is being utilized to a considerable extent by nurseries to produce seedlings for stocks, usually without much discrimination as to variety. The more commonly grown French crab seedlings and also Siberian crab seedlings were included as stocks in the experimental planting.

The clonal stocks are the East Malling Types I, XIII, and XV, Northern Spy variety, and five selections made by the United States Department of Agriculture, Nos. 313, 316, 317, 323, and 329. These latter five have not been introduced and while they are comparatively untested as stocks, they had given previous indications of good performance in a few other locations.

On each stock are four scion varieties, namely, Gallia Beauty, Starking, Staymared, and York Imperial. The trees were propagated by budding, the buds being inserted in the stems of the stocks 6 to 8 inches above the roots. Except in a few cases, 24 trees of each combination of stock with variety were planted.

The arrangement of the trees is in units of six in a row of each combination located in four places at regular intervals over the tract.

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<sup>1</sup>Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 210.

The trees in each third row are on one or the other of the clonal stocks Nos. 316 and 329. These two stocks appear in alternate third rows to provide criteria with which to compare the stocks in the rows adjacent to them. By this arrangement each of the other stocks is situated next to one of these standards, thus partially avoiding the complication of the above mentioned fertility gradient which extends at right angles across the stocks. The trees are spaced 20 by 20 feet.

Losses of trees have been rather small except on two stocks. Of those on Malling XIII, about one-half died during the first 2 years. This stock apparently suffers more quickly from drouth than others, at least while young. The survivors are practically equal in size with those on the adjoining No. 329, except Staymared which are noticeably smaller. On Red Siberian stocks, besides losses during the first 2 years all four varieties were so variable and developed so many stunted trees that they were discarded after 4 years.

The growth during five seasons is indicated by the trunk circumferences in Table I, giving the means and the average difference between these and the adjoining Nos. 316 or 329 with the probable errors of these differences.

The two clonal stocks Nos. 316 and 329 (compared in the first line of Table I), have produced trees that are nearly equal in size at present. Comparing the trees on the other stocks with whichever of these two is situated in the adjoining row, some differences in size are found among the four varieties.

The Gallia Beauty trees on seedlings of Rome Beauty, Jonathan, McIntosh, Northern Spy, and the clonal stocks Malling XIII and Nos. 323, 313, and 317 are nearly the size of the clonal stocks with which they are compared. If odds greater than 20 to 1 are regarded as significant for a difference, those on seedlings of Delicious, French Crab, Grimes Golden, and Wealthy are smaller, and differ among themselves by an insignificant amount. Northern Spy variety as a stock induces dwarfing of Gallia Beauty here as it does to a lesser degree in the other three varieties. Malling I has still more dwarfing effect.

Starking trees on the seedlings of Rome Beauty, Jonathan, McIntosh, Delicious, Wealthy, and Winesap are in the same size class as the clonal stocks Malling XIII and XV, and Nos. 323 and 317. Those on Northern Spy seedlings, French Crab, and Grimes Golden are in a group of smaller size.

Staymared trees similar in size with the clon used for comparison include those on seedlings of Rome Beauty, Jonathan, Northern Spy, French Crab, and Winesap. Those on Grimes Golden, significantly smaller in the other three sorts, are smaller here also but with odds of only about 12 to 1. Those significantly smaller on seedling stocks are McIntosh, Delicious, and Wealthy. Those on clonal stocks Nos. 323, 313, and Malling XV also are smaller.

The York Imperial trees on seedlings of Jonathan are larger than those of their comparative clon by a narrow margin of significance. Those on seedlings approximating the size of those on the adjoining clon are on seedlings of McIntosh, Northern Spy seedlings, and French



Crab, while those that are smaller are on seedlings of Rome Beauty, Delicious, Grimes Golden, Wealthy, and Winesap.

Some fruit has been borne but the total amount is small. The yield varies so much among individual trees that the averages have little significance. Malling I and Northern Spy variety as stocks apparently are inducing early flowering of Gallia Beauty, Staymared, and York Imperial. On the seedling stocks a number of individuals more or less stunted in growth have come into bearing earlier and much heavier than the average for their group.

#### DWARFING STOCKS

The block of trees on Malling II and IX consisted originally of 21 trees of each of the six varieties, York Imperial, Gallia Beauty, Jonathan, Staymared, Golden Delicious, and Starking, on each of the two stocks. The trees on the two stocks are planted alternately in the rows.

From the standpoint of commercial fruit production, Malling II is proving decidedly superior to Malling IX. While all six varieties on Malling II exhibit indications of dwarfing, expressed both in size of the trees and early bearing, the trees are growing well and give promise of profitable yields in the near future. No trees on this stock have been lost. Some scion-rooting is found with Malling IX, especially in Golden Delicious, although the unions had been made rather higher on the stems than normal. This objectionable development points to high budding as a special precaution in propagating trees on dwarf stocks, followed by care when they are set out to keep the unions above the soil.

The mean trunk circumferences (in millimeters) of the trees on Malling II after the 1937 season, the difference in its favor compared with Malling IX, and the probable error of the difference are as follows:

York Imperial,	mean 179, difference $60 \pm 5.12$
Staymared,	mean 160, difference $49 \pm 4.44$
Gallia Beauty,	mean 153, difference $41 \pm 4.09$
Starking,	mean 170, difference $45 \pm 4.35$
Jonathan,	mean 157, difference $17 \pm 3.90$

Of these five sorts all but Jonathan have already been dwarfed too much by the Malling IX stock to be profitable in a commercial orchard even though most of them so far have borne better than those on Malling II. The total yield in the dwarf block has not as yet been large enough to offer a good basis for comparison, averaging only a few pounds per tree. In the case of York Imperial on Malling IX the trees are so small that at best they can outyield those on Malling II only until the latter bear a fair crop. This variety does not appear adapted to Malling IX under the conditions here even though it is slow to come into bearing on the usual standard stocks. On Malling II the trees are making growth enough to permit good yields.

Gallia Beauty begins bearing while young, even on French Crab and other commercial stocks, a habit which tends to dwarf the tree suffi-



ciently to favor continued bearing under conditions such as are found here. Hence neither of the two dwarfing stocks appear particularly valuable for this variety.

Jonathan on Malling IX has been dwarfed less than the other sorts although the trees are significantly smaller than those on Malling II. It gives promise of enough growth on both stocks to yield profitably.

Golden Delicious on Malling II has produced a total of 26 pounds per tree and the trees are sufficiently large to yield a commercially profitable crop next year.

Starking has been slow to start bearing even on Malling IX, although the trees are much smaller than those on Malling II.

Staymared on Malling II is developing trees moderate in growth and has borne a total of 30 pounds per tree, the highest yield in the dwarf block. On Malling IX the trees are very small and have literally borne themselves almost to death. Moreover, the root growth has been insufficient to support the trees without artificial aid. Staymared trees began bending over in 1935 when the first apples were borne but did not break immediately. With the other varieties the failure has been chiefly in 1937 and 1938 when winds broke the trees, snapping them off through the stocks below the unions. The structural reasons for this weakness of Malling IX have been discussed by Beakbane and Renwick (1).

It is interesting to note that mice exhibit great fondness for Malling IX. This may be due partly to the anatomy of the stock and partly to the fact that the trees on type IX tend to "keyhole" in the soil, offering a ready-made tunnel for the rodents to reach the roots. Whatever the reason, mice have attacked trees on type IX rather persistently but at the same time have caused no apparent damage to the alternate trees on type II.

#### SUMMARY

In a 5-year-old orchard of Starking, Staymared, Gallia Beauty, and York Imperial, the growth of the trees on several seedling and clonal stocks is compared with those on two clonal stocks planted in adjoining rows throughout the orchard. Seedlings of Rome Beauty, Jonathan, and McIntosh have in general induced growth approximating that made by trees on the comparative clons. Seedlings of French Crab, Delicious, Grimes Golden, Wealthy, and Winesap have induced somewhat smaller growth and with some exceptions the trees on these stocks belong in the same size class.

Northern Spy variety used for a stock and Malling I already have had some dwarfing effect on the four varieties in this orchard.

Malling II is regarded as a promising stock where some dwarfing is desired as the trees on this stock give indications of early bearing with growth enough to enable profitable yields.

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# Growth and Fruiting of Three Varieties of Pecans on Different Seedling Rootstocks

By B. G. SITTON and F. N. DODGE, *U. S. Department of Agriculture, Shreveport, La.*<sup>1</sup>

A PORTION of the United States Pecan Field Station, Robson, Louisiana, was planted in March and December, 1930, to pecan trees to be used for a pruning experiment. Permanent trees were spaced 50 feet on the square with temporary trees interplanted midway between, making all trees 25 feet apart. This report deals with the growth and fruiting of 53 Mobile, 102 Schley, and 104 Stuart trees that were cut out at the end of the 1937 growing season.

## METHODS

Girths of the tree trunks were measured annually at a marked point about midway between the ground and the lowermost branches, and the cross-section areas calculated. A measure of the size of the top of the trees was obtained in the winter of 1937 by use of a camera. The camera was set up at a measured distance, usually 40 feet, from the tree, and focused. Tracing paper was placed against the ground glass and a line drawn around the image of the tree so as to touch the extremities of the branches. Tracings were made of each tree from two directions at an angle of 90 degrees with each other. The area of each tracing was measured with a planimeter, and the mean area of the two tracings for each tree was multiplied by  $N$  derived from the formula

$N = \frac{d-f}{f}$  to find the area of the spread of the branches of the tree in a

vertical plane. In the formula  $N$  is the number of times the object is larger than the camera image,  $d$  the distance of the camera from the object, and  $f$  the focal length of the lens. For convenience this estimated area will be referred to as the "spread of branches."

This method of estimating the size of the tree tops is not absolutely accurate because there are several sources of error. The irregularities of the outline caused by the strong terminals may actually be very small in relation to the entire tree and if included the area of the tracing would be too great and if omitted, too small. The distance from the camera to the tree trunk was the measurement recorded, but the actual distance may vary with the position of the terminals which determine the outline traced. An error of 6 inches in a distance of 40 feet would result in an error, in the estimated area, of approximately 6 per cent. In spite of such sources of error it is thought that this method gives a reasonably reliable estimate of the size of the tree tops.

After the tracings of the outlines of the tree tops were made, the trees were cut by sawing the trunks as close to the ground as possible

<sup>1</sup>The trees used in this study were planted and grown for 4 years under the supervision of Mr. J. L. Pelham. Mr. E. P. Akin assisted in making tracings of the trees and in calculating the data.

and the entire tops were weighed. Yield of pecans in pounds were recorded each year, but the 1937 yield was the first of sufficient size for use in making comparisons.

Statistical constants based on the various measurements of the size of the tree tops and the yield of fruit were calculated according to methods of Love (2), Love and Brunson (3), and Snedecor (4).

Some of the Mobile trees had been budded on seedling *Hicoria pecan* rootstocks and others on seedling *H. aquatica* rootstocks. The other two varieties were on seedlings of two *H. pecan* varieties, Moore and Waukeenah. Seed of these two varieties are used by many nurseries for growing rootstocks. *H. aquatica* has been used as a rootstock on poorly drained soils. The plan for the pruning experiment was changed between the time of planting of the trees and the initiation of the experiment, and this reduced the number of pairs available for comparison. Eighteen 8-year-old trees of the Mobile variety on *H. pecan* rootstock were paired with an equal number on *H. aquatica* on the basis of similarity in height of the nursery tree and in pruning treatment. Similarly 11 pairs of 8-year-old Schley, 8 pairs of 7-year-old Schley, and 20 pairs of 7-year-old Stuart trees were made, one of each pair on Moore seedling rootstock and one on Waukeenah. The age of the trees as given is the number of growing seasons after the trees were planted in the orchard. When planted, the trees were unbranched stems of one season's growth and 6 to 7 feet high. The 7-year-old Schley trees were replants and the size of the nursery trees was not recorded in all instances. This leaves some doubt as to the accuracy in pairing in that group of trees.

TABLE I—THE RELATIONSHIP BETWEEN THE DIFFERENT METHODS OF MEASURING THE SIZE OF THE TREE, AND BETWEEN THE SIZE OF THE TREE AND THE YIELD OF PECANS

	Schley	Stuart	Mobile
<i>Spread of Branches with Area of Tree Trunk</i>			
Linear correlation coefficient	+ 0.806	+0.777	+0.947
Linear regression equation*	1293 A + 26.68	1125 A + 66.0	1056 A + 20.97
Standard error of estimate	31.30	26.20	34.40
t test for significance	13.60	12.46	20.87
<i>Weight of Top with Area of Tree Trunk</i>			
Linear correlation coefficient	+ 0.915	+0.816	+0.970
Linear regression equation*	2270 A - 98.0	1833 A - 35.6	1962 A - 115.0
Standard error of estimate	33.40	37.30	50.20
t test for significance	23.05	14.20	26.52
<i>Yield of Pecans with Area of Tree Trunk</i>			
Linear correlation coefficient	+0.522	+0.221	+0.615
Linear regression equation*	39.1 A - 1.89	4.89 A - 0.43	46.8 A - 3.24
Standard error of estimate	2.16	0.62	5.71
t test for significance	6.13	2.29	5.57
<i>Yield of Pecans with Spread of Branches</i>			
Linear correlation coefficient	+0.463	+0.185	+0.724
Linear regression equation*	0.0222 S - 0.74	0.0028 S - 0.32	0.050 S - 5.40
Standard error of estimate	2.25	0.62	4.99
t test for significance	2.51	1.90	7.51

\*The following symbols are used in equations in this table, A, cross-section area of the tree trunk in square feet; S, spread of branches in square feet

## PRESENTATION OF DATA

The linear correlation coefficients between the various measures of the size of the trees are of the order of + 0.89 (mean of values in Table I) and are highly significant statistically. The regression of the spread of the branches and of the weight of the tree tops on the cross-section area of the tree trunks is linear, with small standard error of estimates and highly significant coefficients of  $X$ . The slope of the regression lines is smallest for the Stuart variety, intermediate for the Mobile variety and largest for the Schley variety. The high correlation coefficients and the small error of estimate of the regression coefficient indicate that either the spread of branches, weight of tops, or cross sectional area of the tree trunks, offers a reliable measure of the size of the trees used in this study (Table I). The area of the tree trunk is probably subject to smaller error and is more readily determined.

Regression of yield of pecans on the cross-section area of tree trunks and on the spread of branches under the conditions of these studies with the Schley and Mobile varieties approaches a straight line, although a second degree curvilinear regression equation results in a smaller standard error of estimate. The yield from the Stuart variety was so small that no dependence can be placed either in the correlation coefficient or the regression equations.

The data indicate that under the conditions of these studies the area of the tree trunks of young pecan trees is a reliable method of pairing for setting up experiments. Waring (5), showed that the yield of apple trees was correlated with increase in circumference of the tree trunk the preceding year, and Anthony (1) suggested the use of trunk circumference in pairing apple trees for fertilizer experiments.

The effects of Moore and Waukeenah seedling rootstocks on the cross-section area of the tree trunks and the yield of nuts of Schley and Stuart pecan trees are shown by the data in Table II.

Eight-year-old trees of the Schley variety on Moore seedling rootstocks averaged 1.15 times larger than those on Waukeenah seedling rootstocks. The difference in cross-section area of the tree trunks is

TABLE II—COMPARISON OF THREE PECAN VARIETIES GROWN ON MOORE AND WAUKEENAH SEEDLING ROOTSTOCKS WITH REFERENCE TO THE 1937 CROSS-SECTION AREAS OF THE TREE TRUNKS AND THE 1937 YIELDS

	Eleven Pairs of 8-year-old Schley		Eight Pairs of 7-year-old Schley		Twenty Pairs of 7-year-old Stuart	
	Cross-Section Area of Tree Trunks (Square Feet)	Yield of Pecans (Pounds)	Cross-Section Area of Tree Trunks (Square Feet)	Yield of Pecans (Pounds)	Cross-Section Area of Tree Trunks (Square Feet)	Yield of Pecans (Pounds)
Mean difference by which trees on Moore rootstock exceeded those on Waukeenah rootstock	0.0245	1.9	0.011	2.9	0.021	0.15
Mean value for all trees	0.178	4.85	0.173	4.61	0.162	0.33
Mean difference/mean	13.9%	39.2%	6.5%	63.5%	12.9%	45.1%
Standard deviation of the difference	0.020	2.6	0.031	1.8	0.027	0.77
Odds	618:1	44:1	5:1	587:1	434:1	4:1

13.9 per cent of the mean of all of the trees in the group, and this difference is highly significant. The 8-year-old Schley trees on Moore seedling rootstocks gave an average of 1.5 times the yield of those on Waukeenah seedling rootstocks. The difference was 39.2 per cent of the mean yield of all of the paired trees and is significant.

Seven-year-old Schley trees on Moore seedling rootstocks averaged only 1.07 times larger than those on Waukeenah seedling rootstocks. Four of the eight trees on Moore seedling were larger, and three smaller than the trees on Waukeenah seedling stocks paired with them. This difference is not significant. The data do not show why these 7-year-old trees did not follow the same trend as the 8-year-old trees. It is possible that the three pairs of trees on Waukeenah seedling stocks which were the largest in 1937, were also largest when planted in the orchard. The 7-year-old Schley trees on Moore seedling rootstocks gave an average of 1.9 times the yield of those on Waukeenah seedling rootstocks. The difference in yield was 63.5 per cent of the mean yield of all of the trees in the group and is highly significant.

The 7-year-old Stuart trees on Moore seedling rootstocks averaged 1.14 times larger than those on Waukeenah seedling rootstocks. The difference in cross-section area of the tree trunks was 12.9 per cent of the mean area of all the trees in the group and the difference is highly significant. The yield of all of the Stuart trees was very small and 13 of the 40 trees in the group did not produce any pecans. The trees on the Moore seedling rootstocks gave an average of 1.6 times the yield of those on the Waukeenah. The difference in this case is not significant.

While in most instances there are significant differences in size of tree and production of pecans in favor of the trees on Moore seedling rootstocks, the differences are small and it is doubtful whether they would justify the use of Moore nuts for growing rootstocks to the exclusion of Waukeenah or some other small variety which might be purchased at lower prices. The differences shown by these data as well as by observations made in commercial nurseries on stand, uniformity, and vigor of trees grown from seed from different sources indicate the need of further investigation of rootstocks for pecan trees.

The effects of seedling *Hicoria pecan* and *H. aquatica* rootstocks on the cross-section area of the tree trunks and yields of 8-year-old Mobile pecan trees are shown by the data in Table III. The trees on *H. pecan* seedling rootstocks averaged three times larger than those on *H. aquatica* rootstocks. The difference in cross sectional area of the tree trunks was 80.5 per cent of the mean area of all the trees in the group and is highly significant.

The Mobile trees on *Hicoria pecan* seedling rootstocks yielded an average of nearly four times as many pecans in 1937 as did those on *H. aquatica* rootstocks. This is an average difference of 9.3 pounds per tree or 118.7 per cent of the mean yield of all the trees in the group. The odds are greater than 9,999 to 1 against a difference as great as this being due to chance alone.

The trees growing on *Hicoria aquatica* rootstocks were chlorotic each year after they were planted in the orchard. This chlorotic condition was partially corrected 1 year by a spray of ferric sulphate.

TABLE III—THE EFFECT OF SEEDLING *Hicoria pecan* AND *H. aquatica* ROOTSTOCKS ON THE CROSS-SECTION AREAS OF THE TREE TRUNKS AND ON THE YIELDS OF 8-YEAR-OLD MOBILE PECAN TREES, 1937 (18 PAIRS OF TREES)

	Cross-section Area of Tree Trunks (Square Feet)	Yield of Pecans (Pounds)
Mean difference by which trees on <i>H. pecan</i> stock exceeded those on <i>H. aquatica</i> stock .....	0.167	9.3
Mean for all trees .....	0.207	7.8
Difference as per cent of mean of mean of all trees .....	80.5%	118.7%
Standard deviation of difference .....	0.055	7.9
Z test of significance .....	3.05	1.18
Odds .....	9999:1	9999:1

Since the only known difference between the two groups of Mobile trees was the type of rootstock, it is concluded that the observed difference in size of trees and yield of pecans was due to the rootstocks. The *Hicoria aquatica* rootstocks apparently are not adapted to the highly alkaline soil of the United States Pecan Field Station at Robson, Louisiana. Incompatability between *Hicoria aquatica* rootstock and *H. pecan* scion might be considered a possible cause for the differences observed in the Mobile variety on the two rootstocks in this soil, since two symptoms of incompatability were observed, that is, dwarfing of the scion and chlorosis of the foliage. These symptoms, however, do not always develop in pecan trees propagated on *H. aquatica* rootstocks. Trees of other pecan varieties on *H. aquatica* rootstocks growing on soils having an acid reaction have been examined without finding marked dwarfing or chlorosis of the type observed on the United States Pecan Field Station. No evidence of abnormal unions, such as failure to make vascular connections or the obstruction of unions by deposits of suberized tissue, have been observed.

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## Abnormal Behavior of Newly Set Oldenburg Buds<sup>1</sup>

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**T**UKEY has reported (1) the abnormal behavior of newly set buds of the Early McIntosh apple. A somewhat similar abnormality was observed at the Massachusetts Experiment Station in 1938. About 150 buds of Oldenburg were set in August, 1937, in the usual way on three different Malling stocks of which 133 started growth in the spring of 1938. Only 30 per cent grew normally while the others showed various abnormalities. This first attracted attention just about 4 weeks after the normal time of bloom of this variety.

The buds were cut from some of 22 Oldenburg trees which were 25 years old. These trees bore heavily in 1936 and 1938 but had practically no crop in 1937 when the buds were cut. Examination of these trees, when the abnormal behavior of the newly set buds was observed, revealed no unusual behavior of the lateral buds on growth of 1936. There were a few weak clusters of apples but most of the buds were dormant. There were about a half dozen late blossoms coming from spurs on the older wood.



FIG. 1. (1) Petals almost suppressed, one anther petal-like, double pistil. (2) Balloon-like flower, five enlarged sepals, somewhat defective pistil. (3) Five enlarged sepals, many petals, normal stamens, four parted pistil, elongated pedicel. (4) Globular calyx, no corolla, shriveled stamens and pistil. (5) No corolla, shriveled pistil. (6) Six sepals, no other flower part.

The inserted buds produced, instead of normal leafy shoot growth, all sorts of abnormal flower-like growths and various intergrades between flowers and leafy shoots. Pedicels were usually elongated and

<sup>1</sup>Contribution No. 334 of the Massachusetts Agricultural Experiment Station.

the number of sepals, petals, stamens or pistils increased beyond the normal number or partially or wholly suppressed. Various intergrades of flower parts and leaves frequently appeared, such as stamens that were partly petals, petals that contained chlorophyll and sepals that somewhat resembled leaves.

Most of the abnormal growths developed leafy shoots that grew into good 1-year whips. A casual survey in late summer might not suggest anything abnormal but close examination would reveal, in some trees, slight abnormalities as irregular location of lateral buds and a slightly thickened base of the shoot. Trees that had started normally were a little taller due probably to an earlier start. All the leafy shoots appeared to arise from the axils of leaves, and there was no clear case of a leafy shoot originating from the pistil. There did appear in one or two flowers a weak leafy shoot, apparently from the center of a flower, which failed to grow.



FIG. 2. (1) Normal cluster base bearing one abnormal flower with 3-inch pedicel, leaf-like sepals of variable size and shape, petals greenish and irregular. No pistil or stamens Did not grow. (2) Normal cluster base, terminal flower with normal pedicel, cupped sepals, no petals but with stamens and pistil, also one flower with four enlarged sepals and some of the anthers, petal-like The 8-inch leafy shoot grew from a leaf axil and developed into a normal 5-foot tree. (3) One flower with 3-inch pedicel, seven leaf-like sepals, supernumerary petals, no normal stamens or pistils but one small leaf-like structure in place of pistil which did not develop. The leafy shoot grew to a 3-foot tree. (4) Elongated cluster base bearing three flowers coming from leaf axils, also a terminal flower with no petals, normal stamens and pistils, sepals cup shaped. The other three flowers had four, five and six sepals, extra petals, and normal stamens and pistil Did not grow.

It is difficult to believe that this abnormal or partial differentiation occurred in the nursery, one reason being that it appeared in a majority of the buds on one variety while there was not a single case among



more than 1,500 buds of other varieties subjected to practically identical conditions in the nursery. If it occurred before the buds were cut from the parent trees, why did no abnormal blossom clusters appear on the trees? The answer may be that there were abnormal buds on the trees but all of them remained dormant. It is to be regretted that no microscopic examination was made of these dormant buds. Perhaps the transfer of the buds to a new situation on the clonal stocks upset the normal process of differentiation. The stimulus of forcing a single bud to grow may have forced growth of partially differentiated flower buds which would have remained dormant had they remained on the original tree.

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## The Use of Chemicals in Rooting Raspberry Leaf-Bud Cuttings<sup>1,2</sup>

By ERNEST ANGELO, *U. S. Field Laboratory for Tung Investigations, Bogalusa, La.*

**S**ELECTED black raspberry seedlings have been propagated successfully at the University of Minnesota Fruit Breeding Farm by means of leaf-bud cuttings following the method described by Stoutemyer, Maney and Pickett (1) with slight changes as reported in 1937 by Angelo (2). The possibility that treatment with certain chemicals might induce larger root systems in a shorter time lead to the test as here reported.

During the summer of 1938 the greenhouses on the Fruit Breeding Farm were dismantled in preparation for the building of new and larger houses. In order to continue the propagation of raspberry and strawberry seedlings a temporary cloth house was constructed of unbleached muslin. Propagating beds were built on the ground inside this house with additional shade being supplied immediately over the beds by muslin covered sash. The beds were 12 inches deep and contained 6 inches of washed, sharp sand used as the rooting medium. Leaf-bud cuttings of black raspberry were placed in the house early in July and rooted as successfully as in previous years in the greenhouse.

On August 26th, 325 leaf-bud cuttings were taken from one selected raspberry seedling; the cuttings being made as uniformly alike as possible. Three hundred of these were divided at random into four groups of 75 each. One group was placed in tap water, one in a water solution (2.2 milligrams of indolebutyric acid per 100 cubic centimeters tap water) of the commercial growth promoting substance Auxilin, one in a water solution (3 milligrams of indole-acetic acid per 100 cubic centimeters tap water) of the growth promoting substance Hormodin, and one group was placed in the sand rooting medium. The first three groups were kept in the water and solutions, with about 1 inch of the petiole beneath the surface, for 16 hours and were then transferred into the sand in the same frame with those placed there direct from the field.

All the cuttings received the same attention, which consisted of careful watering when needed, until September 20th. At this time they were dug and data, as recorded in the following table, were secured.

It is interesting to note that holding the cuttings in tap water alone for as long as 16 hours was very detrimental. Nearly three times as many of the cuttings treated in this manner had died at the end of this test as in the case of the cuttings that went direct to the rooting medium. Exposing the cuttings to water alone for 16 hours also adversely effected the amount of rooting on those that survived.

Auxilin in the concentration and duration of the treatment used

<sup>1</sup>Paper No. 1670 Scientific Journal Series Minnesota Agricultural Experiment Station.

<sup>2</sup>The work covered in this report was completed while the author was a member of the Division of Horticulture, University of Minnesota, St. Paul, Minn.

## EFFECT OF DIFFERENT TREATMENTS ON THE ROOTING OF BLACK RASPBERRY LEAF-BUD CUTTINGS

Number of Cuttings	Treatment	Condition and Number Rooting (Per Cent) 28 Days After Making Cuttings					Condition of Leaflets
		Dead	Heavy Rooting	Medium Rooting	Little Rooting	No Rooting	
75	From field direct to sand	12.00	41.33	21.33	10.67	14.67	Normal green
75	16 hours in tap water, then to sand	33.33	14.67	14.67	24.00	13.33	Slight yellowing
75	Hormodin 16 hours then to sand	22.67	2.67	22.67	32.00	20.00	Very yellow
75	Auxilin 16 hours then to sand	54.67	2.67	9.33	20.00	13.33	Very yellow

(2.2 milligrams indolebutyric acid per 100 cubic centimeters tap water) proved very detrimental to the survival and rooting of the cuttings. Hormodin (3 milligrams indole-acetic acid per 100 cubic centimeters tap water) while not killing nearly so many of the cuttings as Auxilin, reduced the amount of rooting as compared to the cuttings that were placed directly into the rooting medium. No doubt had other concentrations, lengths of exposure and other carriers been used, the results would have been quite different. Hitchcock and Zimmerman (3) in working with approximately 100 varieties of cuttings point out that the effective concentrations used depended upon the duration of treatment, variety of cutting and the kind of growth substance used. Brase (4) in reporting on the rooting of softwood cuttings says, "The optimum concentration of the growth substance, the length of treatment, and the physical condition of the cuttings to be rooted must be determined".

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## The Affinity of Varieties other than Grimes on Virginia Crab Stocks

By J. A. McCLINTOCK, *Purdue University, Lafayette, Ind.*

IN 1925 Maney (1) recorded that Virginia Crab, as a stock, makes a perfect union with practically every variety grafted upon it. Reporting further on stocks in 1934, Maney and Plagge (2) reported that Grimes and Jonathan had thrived better on Virginia Crab than on French Crab in commercial Iowa orchards for a period of 40 years. In 1930 Cullinan (3) presented evidence that the growth of Grimes had been invigorated by the Virginia Crab stock, and that in its first bearing year Grimes had produced a larger total yield of fruit on Virginia Crab than on any of the other seven stocks which first fruited in 1930.

The first report which indicates that Virginia Crab may not always prove congenial was published in 1933 by Lantz (4). He reported that both Grimes and Starking made variable growth on Virginia Crab, some trees being normal while others were deficient in vigor.

Since 1931 the writer has continued the study of the Virginia Crab as a stock in Indiana. Yearly growth and yield records supplied reliable evidence that with continued growth Virginia Crab retained its superiority as a stock for Grimes. The extent of this superiority is reported by McClintock (5), who in 1937 presented evidence that Virginia Crab not only increases the yield of Grimes fruits per tree, but also increases the size of the individual fruits over those produced by Grimes on 12 other stock combinations.

Uniformly good results obtained in Indiana with Grimes on Virginia Crab in contrast to the variable results reported by Lantz from Iowa indicated the need for further tests to determine the affinity of other varieties for Virginia Crab.

The test plantings at Lafayette consist of 12 trees each of Blackjon, Blaxtaman, Gallia, Golden Delicious, Grimes, McIntosh, Richared, Starking and Turley, all scaffold worked on Virginia Crab. The records consist of measurements of all linear top growth of each variety from the Virginia Crab scaffolds to the tips of the branches at the end of the 1938 growing season. Arranged in the order of their total growth the varieties rank as follows: Golden Delicious, Turley, McIntosh, Gallia, Starking, Grimes, Richared, Blackjon, and Blaxtaman. If Golden Delicious, with the greatest growth, is figured at 100 per cent, then the growth of Turley would be 97 per cent; McIntosh 94 per cent; Gallia 67 per cent; Starking 67 per cent; Grimes 65 per cent; Richared 56 per cent; Blackjon 50 per cent and Blaxtaman 17 per cent. It is thus seen that of the nine varieties in this test, five have made more growth than Grimes during the five seasons since the unions were made.

While Richared and Blackjon do not show as high a percentage of growth as Grimes they are not conspicuous for making poor growth; but in the case of Blaxtaman the growth is poor, and indicates a lack

of affinity. It has also been observed in the nursery that Blaxtaman gives a poorer set of buds and less vigorous growth than the other varieties tested to date. When some of the undesirable characteristics of Stayman are considered, its poor response to date in these studies gives added emphasis to the value of the large fruited, highly colored Turley, as a member of the Winesap group, which does appear to make good growth on the Virginia Crab stock.

It is too much to expect that Virginia Crab will prove the best stock for all varieties, but to those who desire to take advantage of the cold and disease resistance of this stock without further delay, this report may be of value in indicating what may be expected.

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# Further Notes on the Malling Clonal Stocks in Relation to McIntosh and Wealthy<sup>1</sup>

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IN 1935 a preliminary report was made concerning the comparative performance of 7-year-old McIntosh and Wealthy trees on Malling stocks, on seedling roots, and on their own roots (5). The object of the present paper is to place on record a further accounting of performance based on a 10-year record of growth and production. The principal comparisons are concerned with the two varieties on eight rootstocks with either 13 or 14 trees making up each combination. A summarization of the performance of the varieties on some dwarfing stocks is dealt with separately because the limited number of individuals in these cases makes the use of statistical treatment out of the question. An exception is the growth rate table which includes one of these semi-dwarfing stocks and one of the dwarfing stocks for comparative study.

The orchard has been managed on the cultivation-cover crop system with nitrogen fertilization only until 1936 when potassium was included in the annual application. Considered from a commercial standpoint, growth and production have been satisfactory, except in certain dwarf and semi-dwarf combinations.

Tables I and II summarize the growth performance of the two varieties on several stocks. The stocks are arranged in the order of decreasing trunk area in 1938. This order follows that of the 1934 measurements reasonably well.

TABLE I—MEANS OF CROSS-SECTIONAL TRUNK AREAS WITH COEFFICIENTS OF VARIABILITY FOR MCINTOSH ON SEVERAL STOCKS

Stocks	Means Cross-Sectional Area Cm <sup>2</sup>		Coefficients of Variability (Per Cent)	
	1934	1938	1934	1938
XII . . . . .	110.86 ± 4.20	279.64 ± 9.86	21.0	19.6
XVI . . . . .	110.54 ± 2.56	249.62 ± 7.37	13.6	15.8
O.R. . . . .	99.71 ± 6.67	232.93 ± 14.54	37.1	34.6
S.R. . . . .	90.02 ± 3.82	224.93 ± 7.01	23.5	17.3
XV . . . . .	73.79 ± 4.24	206.50 ± 8.23	31.9	22.1
X . . . . .	83.85 ± 6.61	204.31 ± 14.05	42.0	36.8
XIII . . . . .	70.46 ± 7.10	186.62 ± 16.36	53.9	46.9
I . . . . .	69.95 ± 3.50	161.46 ± 8.97	26.8	29.7

TABLE II—MEANS OF CROSS-SECTIONAL TRUNK AREAS WITH COEFFICIENTS OF VARIABILITY FOR WEALTHY ON SEVERAL STOCKS

Stocks	Means Cross-Sectional Area Cm <sup>2</sup>		Coefficients of Variability (Per Cent)	
	1934	1938	1934	1938
XII . . . . .	75.54 ± 3.90	149.00 ± 7.13	27.6	25.6
XVI . . . . .	70.00 ± 1.77	140.43 ± 2.94	14.0	11.6
XIII . . . . .	52.57 ± 2.66	118.93 ± 6.14	28.0	28.6
S.R. . . . .	57.54 ± 3.98	116.54 ± 8.20	36.9	37.7
XV . . . . .	52.92 ± 2.05	112.77 ± 3.03	20.7	14.4
O.R. . . . .	53.46 ± 2.98	109.38 ± 5.91	29.8	28.9
X . . . . .	48.43 ± 2.48	102.21 ± 4.30	28.4	23.4
I . . . . .	7.28 ± 0.84	11.73 ± 1.31	56.7	52.3

<sup>1</sup>Contribution No. 333 of the Massachusetts Agricultural Experiment Station.

McIntosh/Malling XII, Malling XVI and on its own roots have maintained superiority over the seedling rooted trees. The 1938 size difference over seedling roots is highly significant (2) only with Malling XII. However, low odds suggest that the greater size of Malling XVI trees as compared with seedling rooted trees may possibly be significant also. On the other hand, in only one comparison, the semi-dwarfing stock Malling I combination, do seedling-rooted McIntosh reveal significant superiority.

With Wealthy also, Malling XII and Malling XVI have proved to be superior stocks. Both combinations are significantly more vigorous than the seedling-rooted trees as well as the own-rooted trees. Malling XIII has done comparatively better with Wealthy than with McIntosh. Definite incompatibility has characterized almost from the start the Wealthy/Malling I combination. The trees are very much dwarfed with some swelling at the unions.

With regard to uniformity of growth, it is evident from the variability coefficients that clonal roots have played little part in standardizing performance in this orchard. With McIntosh, the differences are in favor of the seedling rooted trees but are generally insignificant. Only Wealthy/Malling XVI and Wealthy/Malling XV show significantly less growth variation than the trees on the usual seedling roots. The investigations of Spinks at Long Ashton reiterate the failure of clonal roots to reduce tree variability materially (6). Other work suggests the possibility of variable results (9). Variability has, in most instances, decreased as the trees have grown older. This is in agreement with the findings of Upshall (8) and others.

Tables III and IV give mean total yields with standard deviations and coefficients of variability.

TABLE III—MEANS OF TOTAL YIELDS FOR THE PERIOD 1933 TO 1938  
INCLUSIVE, WITH STANDARD DEVIATIONS AND COEFFICIENTS OF  
VARIABILITY FOR MCINTOSH ON SEVERAL STOCKS

Stocks	Means Total Yield (Cwt)	Standard Deviation	Coefficients of Variability (Per Cent)
XVI	11.48 ± .66	3.39 ± .47	29.6
O.R.	8.89 ± .99	5.48 ± .70	61.6
S.R.	7.96 ± .66	3.55 ± .47	44.6
X	7.92 ± .82	4.36 ± .58	55.0
XII	7.39 ± .56	2.99 ± .30	40.5
I	5.86 ± .62	3.33 ± .44	56.8
XIII	5.61 ± .79	4.24 ± .56	75.4
XV	4.25 ± .45	2.48 ± .32	58.5

TABLE IV—MEANS OF TOTAL YIELDS FOR THE PERIOD 1933 TO 1938  
INCLUSIVE, WITH STANDARD DEVIATIONS AND COEFFICIENTS OF  
VARIABILITY FOR WEALTHY ON SEVERAL STOCKS

Stocks	Means Total Yield (Cwt)	Standard Deviation	Coefficients of Variability (Per Cent)
XVI	7.02 ± .27	1.48 ± .19	21.0
XII	6.39 ± .54	2.90 ± .38	45.4
S.R.	5.00 ± .47	2.52 ± .33	50.4
XIII	4.54 ± .26	1.43 ± .18	31.4
O.R.	3.90 ± .33	1.78 ± .24	45.5
XV	3.87 ± .22	1.16 ± .15	29.9
X	3.52 ± .28	1.63 ± .20	43.6

McIntosh/Malling XVI has significantly outyielded all the other combinations (Table III). The own-rooted trees produced well but were variable. Other unpublished data indicate that McIntosh will do well on its own roots. The high variability of performance, as reported here, may possibly be traced in part to the development of uneven, often one-sided, root systems brought about by the method used in propagating the own-rooted trees. The yields of the seedling-rooted trees and those on Malling X are significantly higher than that of McIntosh/Malling XV despite the insignificant differences in tree size between them. Trees on Malling XII have yielded relatively poorly considering their size. Malling I, a semi-dwarfing type, has performed quite satisfactorily as has been the case in British Columbia (3).

With Wealthy, as with McIntosh, Malling XVI has taken the lead in fostering production. Wealthy/Malling XVI has significantly outyielded the trees on all of the other roots except Malling XII. This latter stock has performed comparatively better with Wealthy than with McIntosh, while the own-rooted Wealthy have lagged.

As a general rule, the variability in yielding capacity of these varieties to date has not been reduced through the use of clonal- or own-rooted trees. The rather high coefficients lend support to the hypothesis that other factors than rootstock largely control uniformity of yield. With McIntosh/Malling XVI, variability has been appreciably lower than that with seedling roots, but the odds are not sufficiently high to warrant a statement of significance. Only with the Wealthy/Malling XVI combination is the coefficient of variability of yield, 21 per cent, significantly lower than that exhibited by the seedling-rooted trees, 50 per cent. It is interesting to note the greater average variation in yield with McIntosh than with Wealthy.

It seems probable that many of the differences as given in the above tables, whether in yield, growth, or variability, which in this particular test do not display statistical significance should not be discarded as meaningless. Instead they should be taken as indicating possible trends to be substantiated by results elsewhere. This reasoning somewhat similarly applies to the data summarized in Table V with the exception that the data source in this case is relatively meager. This table gives essential performance data for McIntosh and Wealthy trees on six of the dwarfing stocks. The arrangement is in the order of decreasing trunk areas as of 1938.

TABLE V—AVERAGE CROSS-SECTIONAL TRUNK AREAS FOR 1938 AND TOTAL YIELDS FOR THE PERIOD 1933 TO 1938 INCLUSIVE, FOR MCINTOSH AND WEALTHY ON SEVERAL STOCKS

McIntosh				Wealthy			
Stock	Number of Trees	Trunk Area (1931) Cm <sup>2</sup>	Yield 1933-1938 (Cwt)	Stock	Number of Trees	Trunk Area (1938) Cm <sup>2</sup>	Yield 1933-1938 (Cwt)
IV.....	2	237.8	7.89	IV . . .	2	111.2	5.31
V.....	3	158.4	3.56	V.....	3	80.1	2.79
VI.....	3	132.7	4.43	VI.....	2	52.8	2.27
IX.....	2	10.8	.53	II.....	3	27.3	1.27
III.....	1	10.7	.05	III.....	2	16.6	.38
II.....	2	10.2	.00	IX.....	2	5.3	.09



It is at once evident that, among these stocks, three are definitely above the average in vigor of growth and yield. On the other hand, Malling IX, Malling III, and Malling II can be characterized as very dwarfing stocks for McIntosh and Wealthy. The experience of Upshall in Canada with Malling II (7, 8) however, partly contradicts this conclusion and emphasizes the need for duplication of tests before recommendations based on field tests can be made with confidence. Both McIntosh and Wealthy have performed surprisingly well on Malling IV. This concurs with results in England (1). Trees on Malling VI are larger but have produced less fruit per unit area of trunk than those on Malling V. Malling IX has not lived up to its reputation of inducing heavy early bearing (2, 8). This may be accounted for by inadequate culture, since no more intensive methods were used here than elsewhere in the orchard. From our results, it seems to be true that the more a tree is dwarfed the more intensive culture it demands if it is to perform to capacity.

Table VI summarizes growth activity over the 10-year period for the two varieties on ten stocks. The growth rates were determined by the Geometrical Mean formula as described by Moffatt (3) which gives due consideration to the mean sizes of the trees at the start of each period.

TABLE VI—GROWTH RATES OF MCINTOSH AND WEALTHY ON SEVERAL STOCKS FOR THREE PERIODS BASED ON CROSS-SECTIONAL TRUNK AREAS

Stock	McIntosh			Wealthy		
	1928-1930	1931-1934	1935-1938	1928-1930	1931-1934	1935-1938
XII	53	65	24	50	54	18
XVI	74	65	24	70	57	18
IV	64	57	18	43	53	14
O R	46	54	22	40	47	18
S R	55	62	24	48	56	18
XV	54	62	27	46	56	19
X	63	61	22	63	59	19
XIII	38	57	25	46	56	21
I	70	50	19	59	34	12
IX	38	26	11	48	16	7

There is considerable significant variation in the first period which becomes progressively less as the trees increase in age. The greatest growth rate occurred usually in the second period with a very marked drop accompanying the third period. This decrease must have been due largely to the effect of cropping. It is evident that there is not a perfect correlation between actual mean tree size at any time and the previous growth rate of the trees. This is due to initial size differences. For instance, McIntosh/Malling XVI is smaller than McIntosh/Malling XII even though its growth rate was higher during the first period and equivalent during the subsequent two periods. The latter trees when set in 1928 were almost twice as large as those on Malling XVI. Upshall reported a similar finding (7).

There is some relationship between the growth rate during the last 4 years and the extent of cropping. For instance, with McIntosh, the Malling XV and the Malling XIII trees had the highest growth rates together with the lowest yields. On the other hand, Malling XVI trees

have maintained vegetative growth remarkably well considering their high yielding record. Trees on the dwarfing stocks have steadily slowed down in growth from the start, which may mean that they will tend to reach maturity sooner than trees on the so-called "standard" stocks. The figures as a whole give some indication of further performance but definite forecasting on the basis of existing records seems risky.

### CONCLUSIONS

This paper reports records of performance of McIntosh and Wealthy trees on several Malling clonal stocks ranging from very dwarfing to very vigorous in regard to influence on the scion. Comparison of growth, yield, and variability of these clonal-rooted trees with own-rooted and seedling-rooted trees is made. Among the so-called "standard" stocks, Malling XII has been outstanding in promoting vegetative growth, followed closely by Malling XVI. Both varieties on Malling XVI have significantly outyielded the other combinations.

The other extreme is the record of both varieties on Malling XV. The evidence seems to show that this stock manifests the tendency to delay precocity in scions worked upon it. The other combinations are arranged variously and it is significant that the seedling-rooted trees assume approximately a mean position in all the computations of size and yield. Of the semi-dwarfing stocks, Malling IV and Malling I seem superior. The very dwarfing stocks have performed unsatisfactorily under the conditions of this test.

Variability studies indicate that very little benefit can be expected from the use of clonal-rooted trees in establishing and maintaining performance uniformity in an orchard in Massachusetts.

Computed growth rates reveal the necessity for caution in the interpretation of ordinary size measurements and give a progressive picture of performance which may have some value in forecasting trends.

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## Hardy Rootstocks for the Peach Should Extend Well Above the Surface of the Soil

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THE unusually severe winters of 1933-1934 and 1934-1935 caused serious injury to the wood of peach trees along the Atlantic coast in the northeastern states. This has naturally focused attention upon the matter of hardy stocks for the peach. Many acres of peaches in the Northeast are located in districts where no serious freezing injury occurs to the side and smaller roots of the peach even in a season such as 1933-1934. The major damage occurs to the wood of the trunk extending from slightly below or at the ground level up to the junction with the main branches and may involve them also.

One form of injury is the near killing or complete killing of a band of bark several inches in width upon the main trunk just above the soil. This results in a girdling effect and fungi soon cause rapid decay of the wood.

Another form of injury to the trunks of peach is bark splitting. This is sometimes confined to the lower few inches of the trunk, but often extends to a height of at least 12 to 24 inches. Although the bark upon other portions of the trunk is uninjured, fungi enter from the injured side and rapid weakening and decay of the inner wood occurs.

### INJURY TO THE GREENSBORO

The Greensboro is regarded as one of the hardiest varieties in the Northeast and this is especially true of the fruit buds and twigs. In the winter of 1933-1934, however, trees of this variety experienced more serious trunk injury for a few inches above the ground level than did trees of such varieties as Early Crawford, Dewey, Slappey, Foster, and Fitzgerald.

### MATURE LATE AT SOIL LEVEL

Injury to the bark of the main trunk of peach trees in certain seasons in New Jersey may be partly explained by a condition which occurred in 1934. It was found that the cambium and bark upon the trunks of some seedling peach trees in the nursery was favorable for budding at the soil line as late as October 28. The bark, however, adhered firmly to the trunk at the usual point of budding and above. A number of these seedlings were successfully budded at the soil line. Observations indicate that the wood and bark of the trunks of some varieties of peaches is more susceptible to winter injury than that of others. It is further apparent that hardiness of the lower trunk and resistance to bark injury is not always correlated with hardiness of fruit buds as previously reported (1).

### THE STOCK PROBLEM

Under the climatic conditions which prevail in New Jersey, a hardy root stock budded at the ground level in the usual manner will not prove to be a remedy for the most common forms of winter injury to the trunk of the peach. To be effective, the hardy stock must extend at least 18 inches above the level of the soil. This does not involve any serious problem in propagation. If hardy seedlings are well spaced in the nursery row and provided with good culture, they will be large enough the first summer to bud 18 inches above the ground. If the seedlings are cut off properly above the bud the following spring and grow well, the trunk should have only a very slight crook at the point of budding. If liberal space is allowed such trees in the nursery row, they should branch freely and the side branches should attain sufficient diameter and vigor to permit at least of the partial formation of the head of the tree at the time of planting.

### STOCKS WITH HARDY TRUNKS

Seedling stocks of Elberta, Paragon and many semi-dwarf J. H. Hale types appear to be especially sensitive to trunk injuries at New Brunswick, New Jersey. Seedlings of Iron Mountain, Early Crawford, and Belle have developed noticeably more resistant trunks than the varieties previously mentioned.

Some of the most hardy stocks from a trunk standpoint are apparently to be found among so-called "natural seedlings." It is a somewhat common belief that seedling stocks from the southern Appalachian Mountain regions possess some special factor for hardiness because of their supposedly wild nature. This is not true, however, when they are considered collectively. Many individual trees grown from pits from this area have been set in orchard form at New Brunswick, New Jersey, and their qualities for stock observed.

### VARIATION IN STOCK

The seedling trees obtained from southern stock pits vary greatly in vigor, habit of growth, time of maturity, and hardiness. A few types may be briefly described as follows:

*The Indian Cling Peach:*—This type tends to be relatively vegetative and to grow late in the fall at New Brunswick. Some hardy variations may be found but the type is not regarded as desirable for northern peach districts.

*White-fruited Seedlings with no Red:*—A considerable number of seedlings have appeared in collections of southern pits which develop into large trees but the bloom is almost pure white and the fruits develop no red color either in the skin or the flesh. All such trees at New Brunswick have been quite susceptible to collar injuries even as young seedlings.

*White-Fleshed Seedlings with Red:*—Among seedlings which produce very small fruits well marked with red, a considerable number have been noted which possess good trunk hardiness under New Jer-

sey conditions. There is a wide variation, however, among individuals of this type.

*Yellow-fruited Types*.—The number of yellow-fruited types with small sized fruits has been limited in pit samples but some have been selected and observed. One which is distinctly hardy makes a rather small volume of growth and is quite susceptible to arsenical injury. Such a type would not be desirable for budding high in the nursery because of only medium vigor.

*Red-leaved Types*.—Seedlings with red or copper-colored leaves appear in limited numbers at times among green-leaved types from southern pits. A number have been grown and observed. As a group they have proved to be somewhat more spreading and willowy than either the Indian Cling or the white-fruited, well colored with red type. The seedlings under observation have not been attacked to any considerable extent by the Japanese beetle. The pits do not germinate well the first season if planted in the usual manner in the nursery row in the late fall. This is not due to weak kernels but to a very firm union of the halves of the seed. Such pits, therefore, require special treatment. The seedlings observed make sufficient growth for budding high if they receive proper culture and some have been notably trunk hardy at New Brunswick, New Jersey.

#### SPECIAL STOCKS FOR DISTRICTS

When one considers the effect of environment upon the hardiness of plants it appears likely that some peach stocks that will prove desirable for budding high and furnishing hardy trunks for one region will not be satisfactory in another. There is an abundance of material, however, from which selections can be made.

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## Yields from Young Apple Trees Topworked on Arkansas

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**D**ATA on yields herein reported, constitute one phase of studies (1) underway at the Hood River Experiment Station respecting the character and practical value of 68 intermediate apple stocks of which Arkansas Mammoth (Black Twig) is a promising and numerically prominent one. Their further object is to determine the practicability of orchard renewal and variety rotation by interplanting. Both of the above objectives are commercially important in the Mid-Columbia area because low winter temperatures during 1919, 1924, and 1926, killed or severely injured apple trees which caused their removal.

Yield records were taken annually from 1932 to 1937 inclusive, and their summary constitutes a progress report only. Trees were inter-set (in the center of each intersection) within an 11-acre apple orchard,

TABLE I—AVERAGE YIELDS PER TREE (LOOSE BOXES) FROM APPLE VARIETIES TOPWORKED ON ARKANSAS (BLACK TWIG) COMPARED WITH THOSE OF UNWORKED TREES

Variety	Number of Trees		Age of Trees (Years)*					
			7 to 8		9 to 11		12	
	Un-worked	Top-worked	Un-worked	Top-worked	Un-worked	Top-worked	Un-worked	Top-worked
Newtown	36	163	2.30	.69	5.69	5.55	10.85	
Spitzenberg	11	16	No record	1.17	3.0	7.7	—	8.06
Red Spitzenberg (Goodenough strain)	7	9	1.99	.67	4.78	7.66	—	12.2
Red Spitzenberg (Southern Oregon strain)	2	12	.83	.75	10.00	10.3	—	12.2
Delicious	25	37	8.83	1.24†	9.94	7.13	12.4	14.2
Delicious (Starking)	7	57	3.25	2.81	6.5	8.9	—	16.6
Ortley	9	44	4.97	5.29	9.83	13.1	—	15.0

\*Topworked trees including unworked Newtown and Delicious were planted in spring 1926 and remaining trees (unworked) in 1927.

†Low yield resulted from severe pruning which was necessary during the sixth year to correct a mistake in identity of many scions used.

principally Newtowns, which are now 35 years of age and planted 30 feet by 30 feet on the square. Although competition with older trees for moisture and plant food was an important factor, trees subject to this study grew vigorously. During the past 6 years, the orchard has been in an uncultivated sod of miscellaneous orchard grasses with a small proportion of alfalfa, white clover and other legumes. The orchard was thoroughly irrigated and given an annual, early spring application of commercial fertilizer supplying from 1 to 1½ pounds nitrogen per 30-foot square.

Topworking was done during 1927 and 1928 by budding and supple-

mental grafting to the varieties indicated. Owing to a mistake in the identity of scion material used with Delicious, severe corrective pruning and additional topworking was necessary when trees were 6 years of age. This is reflected in low yields during the 7- to 8-year period. Yields for topworked trees of this variety during the twelfth year were, however, 1.8 boxes greater than those from unworked trees.

Under conditions of this experiment, the general average yield per tree for unworked trees was somewhat greater than that for topworked trees during the initial production period (7 to 8 years of age), but less during the subsequent periods.

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# Scion Rooting on Mature Double-Worked Apple Stocks<sup>1</sup>

By T. J. MANEY, *Iowa Agricultural Experiment Station, Ames, Ia.*

THE increasing use of double-worked apple stocks with particular reference to Hibernial and Virginia Crab where these hardy resistant varieties have been used as stem pieces root-grafted on French seedlings, or other stocks, has resulted in considerable information on the growth characteristics of the topworked combinations above ground but little on the behavior of the under ground portions. Bearing directly on this lack of information, there comes from Australia a recent inquiry in a publication by Thomas (1), who states as follows:

"In the Stanthorpe district within the past 5 years, root-grafted trees have been planted deeply, with the union well below soil level, with the intention of encouraging scion rooting. As very little is known concerning the degree of scion rooting induced, the type of root system formed, the depth of penetration of roots, and the performance of such trees when compared with those on standard rootstocks, a study of certain apple varieties on their own roots has been initiated"

At least a partial answer to this inquiry may be given from some observations made in the spring of 1938 on the rooting of six each of Hibernial and Virginia Crab stocks root-grafted on French seedlings. These stocks, a part of a variety orchard planted in 1925, were topworked in 1926 by budding on the scaffold limbs of the two stocks. Three each of

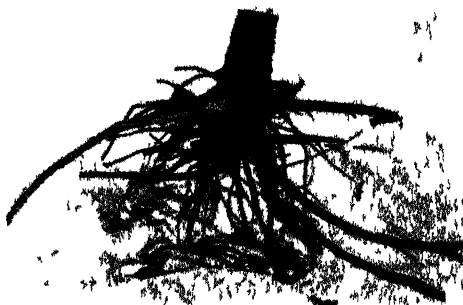


FIG 1 This 13-year-old root-grafted Virginia Crab topworked to Sharon developed strong scion roots

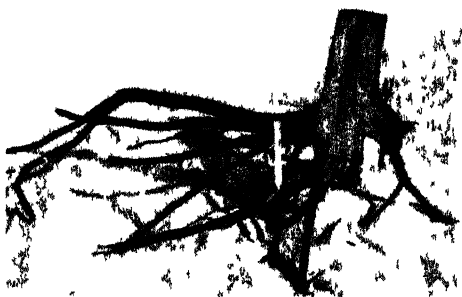


FIG 2 The trunk in Fig. 1 was sectioned and here shows the development of scion roots above the graft union as indicated by the straight line

<sup>1</sup>Journal Paper No. J-608 of the Iowa Agricultural Experiment Station, Ames, Iowa, Project No. 466.



Sharon and Ben Davis were the topworked varieties on each of the stocks.

These 13-year-old combinations were pulled by a tractor early in the spring of 1938 while the ground was sufficiently soft to permit extraction of the trees without great damage to the main roots, as shown in Fig. 1. In all cases the stem pieces had rooted above the graft union, as indicated in Fig. 2, a representative longitudinal section in which the point of union is marked by the horizontal line drawn across the section. In general, the main scion roots developed about 6 to 8 inches above the graft union and were fairly well spaced around the trunk. Apparently these roots were initiated within 2 or 3 years after the stock was planted in the orchard. By the time the trees were removed these scion roots were dominating the root system. In some cases, the original French roots were badly dwarfed or actually killed out.

In an adjoining 20 acre orchard in which Hibernial and Virginia Crab stocks have been planted in rows with 40 trees to the row and each stock topworked to 10 varieties, the 13-year-old trees show unusual uniformity in the growth of trunks and tops (2).

It is possible that this uniformity may be partially accounted for by the fact that the inter-stem pieces have developed scion roots and that these roots are furnishing the conditions which are favorable to the development of growth uniformity in the respective topworked varieties.

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# Root Distribution and Root and Top Growth of Young Peach Trees

By F. F. COWART, *Georgia Agricultural Experiment Station, Experiment, Ga.*

**I**NFORMATION obtained from studies of the root systems of plants is of value in formulating fertilizer and cultural practices as well as in serving as a basis for a better understanding of the variance in tree performance on different soils. Interest has been very manifest in this subject recently, particularly in the field of pomology. Among those who have worked on apple tree root systems are Oskamp (7), Oskamp and Batjer (8), Batjer and Sudds (1), Partridge and Veatch (9), Cullinan (3), Rogers and Vyvyan (10), Yocum (11), and Boynton and Savage (2). The studies which have dealt with the quantitative determination of peach roots in different soil layers have been primarily concerned with the mapping of roots to scale as observed on the surface of a trench dug at right angles to the root system or radiating outward from the tree trunk. Havis (5) and Oskamp (7) have made valuable studies of this nature. The present study involves the use of root mapping as well as a direct determination of the quantity of roots within the respective soil layers by separation of roots from the soil and obtaining weights thereon.

## MATERIALS AND METHODS

One hundred June-budded Mikado (June Elberta) peach trees were selected for uniformity of root and top growth. These were set to the field during March, 1937. Root pruning consisted only in the removal of broken, twisted, and long straggling roots. The tops were pruned to a whip and headed at a height of 15 inches. Three or four well placed shoots were selected for the permanent framework branches as soon as the buds pushed in the spring and all other buds were pinched off as they started growth, during the first growing season. Later pruning has been comparatively light, consisting of a thinning out of crossing branches and a heading back of tall twigs during the first dormant period and the removal of low hanging shoots during the summer of 1938.

The soil on which these trees were grown belongs to the Cecil series. Mechanical analysis shows it to be a sandy loam, according to the classification system of Davis and Bennett (4). However, it very closely approaches the texture of a sandy clay loam. This is a common soil type on which peaches are grown in the Piedmont region of Georgia. The profile is briefly as follows: 0 to 7 inches, grayish-brown sandy loam; 7 to 30 inches, fairly compact, red clay; 30 to 54 inches, compact, red, brittle clay containing scattered concretions of mica and quartz; 54 inches, red, stiff, and very compact clay containing considerable quantities of mica and quartz. The description shows that the top soil (A horizon) is medium heavy underlain by a heavy subsoil.

Fertilizer was applied to the trees as follows:  $\frac{1}{4}$  pound 8-6-6 (N-P-K) per tree March, 1937, and June, 1937; 1 pound 8-6-6 March, 1938, and  $\frac{1}{4}$  pound nitrate of soda per tree June, 1938. Cultivation has consisted of two or three light discings from March through May followed by about two cultivations with a spike-toothed harrow.

Excavations of five trees were made in October, 1937, and of four in October, 1938, following the first and second growing seasons. The area around the tree was laid off into concentric 1-foot circles, with the tree trunk as the center. The soil was dug, either in entirety or in representative parts from each circle in 6-inch increments and the roots separated from the soil, to a depth at which very few or no more roots were found. All dirt was dug and the roots removed from the 0 to 1 and 1 to 2 foot soil zones and to a depth of 18 inches from the 2 to 3 foot zone. From 18 inches downward in the 2 to 3 foot zone two blocks on opposite sides of the tree measuring 2.1 on the inner and 3.1 feet on the outer face were removed. Representative blocks of soil were also removed from the surface downwards in the 3 to 4, 4 to 5, and 5 to 6 foot zones. These blocks measured 2.4 and 3.1 for the 3 to 4 foot zone, 2.5 and 3.1 for the 4 to 5 foot zone, and 2.6 and 3.1 feet for the 5 to 6 foot zone on the inner and outer faces respectively. These blocks represented one-third of the entire area within the 2 to 3, one-quarter within the 3 to 4, one-fifth within the 4 to 5, and one-sixth of the entire soil area within the 5 to 6 foot circular zone. After separation from the soil the roots were washed, separated into different size classes, oven-dried, and the dry weights obtained. The roots were separated into the following sizes: less than 2 millimeter diameter, 2 to 5 millimeters, 5 to 10 millimeters, 10 to 20 millimeters, and above 20 millimeters in diameter. For economy of space the last three size classes are included in one grouping in Tables I and II. Roots less than 2 millimeters in diameter represent or include the absorbing roots.

TABLE I—AVERAGE ROOT DENSITY OF FIVE MIKADO PEACH TREES, END OF FIRST GROWING SEASON, IN GRAMS (DRY WEIGHT) PER CUBIC FOOT OF SOIL

Depth (Inches)	Distance from Trunk (Feet)			Per Cent of Total
	0 to 1	1 to 2	2 to 3	
<i>Roots Less Than 2 Mm Diameter</i>				
0 to 6	2 010	.250	.016	7.5
6 to 12	5.827	1.528	.231	30.5
12 to 18	6 478	1.745	.388	36.0
18 to 24	2.224	.795	.405	17.5
24 to 30	1.096	.439	.062	7.2
30 to 36	.515	—	—	1.4
<i>Roots 2 to 5 Mm Diameter</i>				
0 to 6	.393	.009	—	1.4
6 to 12	9.420	.457	.017	35.8
12 to 18	12.412	1.377	—	54.4
18 to 24	1.327	.256	—	6.9
24 to 30	.348	.021	—	1.4
30 to 36	.064	—	—	.2
<i>Roots 5 Mm Diameter or Larger</i>				
0 to 6	23.850	—	—	28.1
6 to 12	40.096	—	—	47.3
12 to 18	20.602	—	—	24.3
18 to 24	.275	—	—	.3

The mapping of root ends was also used as a method to show root concentration and depth of penetration. The method used was similar to that of Oskamp (7). Circular excavations were made around three trees each of 1- and 2-year-old trees, the inner face of which was 1-foot from the tree trunk. The inner surface of this excavation was marked off into square feet and the root ends charted, in their exact location, on cross-section paper. Accurate measurements and weight of top growth have also been made (Table III).

## RESULTS

The data in Table I and root mappings of 1-year trees show that the roots penetrated to an average depth of 30 to 36 inches. Roots extended 3 feet outward from the tree trunk in either direction or had a total spread of 6 feet. Roots were found to have the greatest spread, as indicated by comparative weights of roots in the soil zones furthest away from the tree trunk, in the 18 to 24 inch layer with both the 1- and 2-year-old trees. Where roots were found beyond 3 feet from the trunk with 1-year trees they were insignificant in quantity.

With 1-year trees 82.9 per cent of the total tree roots were found in the 0 to 1 foot zone, 13.5 per cent in the 1 to 2 foot, and 3.7 per cent in the 2 to 3 foot zone. Forty-eight per cent of the small roots (less than 2 millimeters diameter) were found in the 0 to 1 foot zone, 37.5 per cent in the 1 to 2, and 14.5 per cent in the 2 to 3 foot zone. The 0 to 1 foot zone contained, therefore, about four times the weight of these small roots per cubic foot of soil as did the 1 to 2 foot zone and about 20 times more than the 2 to 3 foot zone. Roots less than 2 millimeters in diameter made up about 25 per cent of the weight of the entire root system. Ninety-eight per cent of all roots in the 2 to 3 foot zone were less than 2 millimeters in diameter.

The greatest total weight of roots was in the 6 to 12 inch soil layer, though a slightly greater density of small roots was found in the 12 to 18 inch layer. The location of these small roots for the 1-year trees was, no doubt, due in some degree to the fact that the main portion of the branched root system was set at this depth when the trees were planted.

The results obtained from the study of the root systems of 2-year-old trees are presented in Table II.

Roots were found to a depth of  $4\frac{1}{2}$  feet and a distance of 6 feet from the tree trunk. With one or two trees a few small roots were found below this level or farther from the tree trunk, but the quantity of these roots was insignificant. The following percentages of roots were found in the different 1-foot concentric soil zones: 0 to 1 foot zone, 67.2; 1 to 2 foot zone, 13.2; 2 to 3 foot zone, 9.3; 3 to 4 foot zone, 4.8; 4 to 5 foot zone, 3.9; and 5 to 6 foot zone, 1.4 per cent. The greatest concentration of roots occurred in the 6 to 12 inch layer, which contained 47.1 per cent of the total tree roots, followed by the 0 to 6 inch layer with 27.5 per cent and by the 12 to 18 inch layer with 15.9 per cent. Roots less than 2 millimeters diameter were almost equally distributed in the soil to a depth of 18 inches. The greatest total quantity of these roots was found in the 1 to 2 foot zone, followed closely, in

TABLE II—AVERAGE ROOT DENSITY OF FOUR MIKADO PEACH TREES,  
END OF SECOND GROWING SEASON, IN GRAMS (DRY WEIGHT)  
PER CUBIC FOOT OF SOIL

Depth (Inches)	Distance From Trunk (Feet)						Per Cent of Total
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	
<i>Roots Less Than 2 Mm Diameter</i>							
0 to 6	5.950	3.042	2.174	.926	.475	.035	22.1
6 to 12	11.382	2.334	1.704	.758	.631	.125	23.3
12 to 18	6.496	2.779	1.215	.844	.836	.291	22.3
18 to 24	1.790	.928	.663	1.088	.837	.609	17.3
24 to 30	1.553	.852	.368	.413	.516	.101	8.6
30 to 36	.621	.408	.174	.187	.200	—	3.4
36 to 42	.419	.336	.108	.090	—	—	1.6
42 to 48	.469	.335	.151	—	—	—	1.3
48 to 54	.252	—	—	—	—	—	.2
<i>Roots 2 to 5 Mm Diameter</i>							
0 to 6	6.717	2.722	.977	.208	—	—	14.6
6 to 12	25.339	2.150	1.781	.567	.147	—	31.6
12 to 18	11.090	3.616	3.442	.708	.217	.051	32.6
18 to 24	2.919	1.076	.941	.496	.584	.014	12.2
24 to 30	2.007	1.081	.232	.080	—	—	4.7
30 to 36	.879	.585	—	.026	—	—	1.9
36 to 42	.956	.333	.044	—	—	—	1.5
42 to 48	.589	.083	.025	—	—	—	.7
48 to 54	.201	—	—	—	—	—	.1
<i>Roots 5 Mm Diameter or Larger</i>							
0 to 6	187.376	1.663	1.441	—	—	—	31.9
6 to 12	317.556	8.856	2.092	.148	—	—	56.9
12 to 18	39.870	7.909	—	—	—	—	10.2
18 to 24	4.796	.326	—	—	—	—	.9
24 to 30	.419	—	—	—	—	—	.1

order, by the 2 to 3, 4 to 5, 3 to 4, and 0 to 1 foot zones. However, the greatest weight, per cubic foot of soil, occurs in the 0 to 1 foot zone and decreases progressively outward (Table II). Marth (6) and Boynton and Savage (2) have pointed out the greater density of small or fibrous roots near the tree trunk but a greater total weight of these roots in soil zones at a distance of several feet from the trunk with mature apple trees. Roots less than 2 millimeters in diameter made up about 18 per cent of the weight of the entire root system.

TABLE III—TOP AND ROOT GROWTH OF 1- AND 2-YEAR OLD MIKADO  
PEACH TREES

Age of Trees	Height (Feet)	Spread (Feet)	Circum- ference (Inches)	Total Dry Weight Tops (Grams)	Root Spread (Feet)	Depth of Root Pene- tration (Feet)	Total Dry Weight Roots (Grams)	Roots in Per Cent of Total Tree Growth
1	3.6	3.5	2.8	338.2	6	3.0	240.6	41.6
2	7.5	8.5	6.3	4417.9	12	4.5	1473.1	25.0

Growth records of 1- and 2-year-old trees are presented in Table III. Weight of tops includes both foliage and branches. The great difference in top-root ratio between 1- and 2-year-old trees is evident. The closer ratio for 1-year trees is probably accounted for by the much greater percentage of the original root growth as compared to top growth left on the trees when they were transferred to the field from the nursery.

The top-root ratio for the 2-year trees agrees very well with that reported by Cullinan (3) for 8-year-old apple trees.

### CONCLUSION

Grown under the existing soil and climate, roots of 1-year-old peach trees penetrate to a depth of 3 feet and attain a spread of 6 feet. Roots of 2-year-old trees penetrated to a depth of  $4\frac{1}{2}$  feet and attained a spread of 12 feet.

A greater weight of roots was found at a depth of 6 to 12 inches and within 1 foot of the tree trunk than at any other location within the soil mass occupied by the roots. The greatest concentration of small roots was found in the 12 to 18 inch level with 1-year trees. They were about equally distributed to a depth of 18 inches with 2-year-old trees.

Roots of young peach trees seem to have no particular difficulty in penetrating the red and fairly stiff clay subsoil, characteristic of the Cecil soil series, to a depth at which the C horizon is encountered ( $4\frac{1}{2}$  to 5 feet). Studies with older trees will show whether peach roots will penetrate this layer.

These studies are indicative of the areas in which fertilizer should be placed for most efficient utilization by the trees.

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## Apple Root Systems Under Different Cultural Systems

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SINCE April 1928 studies of apple roots, their depth and spread under orchard conditions, have been carried out with great care in the experimental orchard of the Aomori-Ken Apple Experiment Station, and in three private orchards where soil conditions differ.

The trees employed for the purpose included ten Ralls, six Jonathan, two Delicious, two Ben Davis, two Smith Cider, and one each of John Sharp and McIntosh, all of which were grafted on *Malus Sieboldii* Rehd., a Japanese native stock. The ages of the trees ranged from 1 to 35 years. The distances between trees were 5 to 6 meters.

Excavation showed that the longest of the apple roots was 13 meters and the average length of main roots was 4 meters. Annual lateral growth of the roots was 0.50 to 1 meter, except a single case in which the annual growth of the root reached 4 meters.

Depth of the roots averaged .26 meter for 1-year plants and 1.2 to 2.5 meters for older trees.

In 8-year-old Jonathan trees the largest number was found between the surface and the 30-centimeter depth, in which region 79 per cent of all the roots was found, and between 30 to 60 centimeter, the amount was 19 per cent, while between .60 to 1.80 meters only 2 per cent of roots occurred. Under 35-year-old Smith Cider trees, 66 per cent were in the first level, 28 per cent in the second, 4 per cent in the third, and between 1.2 to 2.4 meters only 2 per cent.

In the orchard used for excavation, the surface soil was a light gravel loam about .25 meters deep with a very compact gravelly sand subsoil; the water table is 13 meters below the surface.

Root distribution varied with the soil constitution or with conditions in the orchard. Where there is a deep sandy loam, the root growth is rather deep and free. On the other hand, in a volcanic loam with humus surface soil 30 centimeters deep and with very heavy clay hardpan underneath, the roots were little deeper than those in the orchard mentioned above, but the taproots were rather numerous and smaller

TABLE I—CULTURAL METHODS AND ROOT DISTRIBUTIONS

Treatment	Diam. of root (Cm)	Numbers of Roots Distance from Main Trunk (Cm)					
		30	90	190	290	390	490
Broadcast manure with cultivation .. . . .	Above 1	31.5	14.0	4.5	—	—	—
	.6 to 1	35.0	29.5	26.0	10.0	3.0	—
	.01 to .5	29.5	21.0	18.0	9.5	2.5	0.5
	Total roots	96.0	64.5	48.5	24.5	5.5	0.5
Ring manure with no cultivation . . . . .	Above 1	12.0	19.5	12.0	3.5	0.5	—
	.6 to 1	3.5	7.5	9.0	6.5	2.0	—
	.01 to 0.5	1.0	5.0	18.5	25.0	1.5	—
	Total roots	16.5	27.0	29.5	35.0	3.5	—

roots were found. In such soil, however, the water table rises to 1 meter in early spring. This unfavorable drainage is probably injurious or occasionally fatal to root growth below this level. In such soil drainage and breaking down of the hardpan subsoil would be necessary.

#### ROOT SYSTEMS UNDER DIFFERENT CULTURAL METHODS

The distribution of roots was affected by the cultural methods. Broadcasting manures or fertilizers, with proper cultivation, increases the numbers of roots consistently. With the ring manuring method (circular furrow at certain distance from the main trunk) with non-cultivation except a shallow hoeing for weeding, the root distribution was irregular and the number of small roots increases rather centrifugally as shown in Table I and Figs. 1, 2, and 3.

As shown in Table I and by Fig. 1, the numbers of the total roots and fine roots of the trees under the broadcast manuring method with cultivation were far greater than with ring manuring. This indicates a small absorbing area under the latter method.

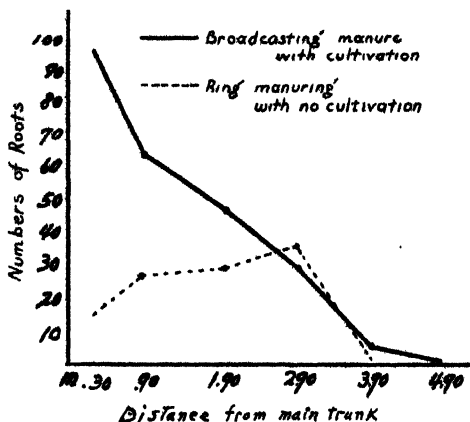


FIG. 1. Cultural method and root distribution.



FIG. 2. Root system under the broadcast manures and proper cultural method. A regular growth and great number of roots.





FIG. 3. Root system under the ring manuring with no cultivation method.  
Irregular growth and fewer roots.

#### YIELD OF APPLES AND MANURING METHODS

The relationship between yield and manuring methods was quite close in the long time experiments. The yield of apples under the former method, above mentioned, was about 20 per cent greater than that under the latter method, even with a double quantity of manures (see Table II).

TABLE II—MANURING METHODS AND YIELD OF RALLS APPLE

Treatment	Average Yield of 9 Years (1927 to 1935)		
	Number Fruit per Tree	Total Weight per Tree (Kilograms)	Average Weight Each Apple (Grams)
<i>A Orchard*</i>			
Broadcast with cultivation . . . . .	569	93.597	164
Ring manuring, no cultivation . . . . .	597	92.929	155
Average Yield of 14 Years (1920 to 1933)			
<i>B Orchard†</i>			
Broadcast with cultivation . . . . .	281	42.147	150
Ring manuring, no cultivation . . . . .	241	33.787	138

\*9 trees 30 years old, 9 meters apart.

†10 and 5 trees respectively, 28 years old, 9 meters apart. Manure used for the broadcasting and cultivation was always one-half of the ring manuring method.

In this investigation the apple root growths were .5 to 1 meter each year, and therefore the roots will occupy all the soil area over the orchard in 5 to 6 years after planting, with 8 to 9 meters spacing of trees.

# Nursery Tests with Grape Rootstocks<sup>1</sup>

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**S**TUDIES with grapes at Winter Haven, Texas, have shown good adaptability as far as climate is concerned, particularly with varieties of *Vitis vinifera*. The chief limiting factor seems to be susceptibility to root-rot (*Phymatotrichum omnivorum*), a fungus disease native to the area. Varieties of *V. vinifera* are particularly susceptible to this disease.

Studies on resistance of plants to *Phymatotrichum* root-rot have been made for a number of years in Texas (1, 6). These studies indicated considerable resistance in the varieties Champanel, Dog Ridge, Marguerite, and some others. Resistance was also indicated in the species: *Vitis candicans*, *V. champini*, *V. berlandieri*, and *V. longii* (Solonis). Since the first three species are all native to Southwest Texas, there was a good opportunity to study wild selections with a view to possible use as rootstocks.

Rootstock studies have been reported upon by Husmann (3), and by Bioletti and others (2) in connection with resistance to grape phylloxera. Snyder (5) has reported on susceptibility to nematode. Table I summarizes present information on some of our native species of grapes in Texas. There is, of course, considerable variation between selections within the species and the relative estimates of the species given in Table I are chiefly valuable in indicating where good resistant stocks may be found. Rooting from cuttings is an important characteristic in determining the relative value of a stock. Information on

TABLE I—RESISTANCE OF SOME TEXAS GRAPE SPECIES

Species	Relative Resistance to			Rooting from Cuttings
	Phylloxera (3)	Root Rot (6)	Nematode (5)	
Arizonica	Medium (4)*	Medium	Poor	Medium (4)
Berlandieri	Good	Good	Medium	Poor
Candicans	Good	Good	?	Poor to medium
Champini	Medium	Good	Good	Good
Cinerea	Good	Medium	?	Medium
Cordifolia	Good	Medium	?	Medium
Doaniana	Medium	?	Good to Medium	Good (4)
Lincecumii	Medium	Medium	Medium	Poor
Longii	Good	?	Good	Good (4)
Monticola	Good	Medium	?	Poor to medium
Rotundifolia	Very good	Medium	?	Poor
Rupestris	Good	Poor	Poor	Very good
Treleasi	Medium (4)	?	?	Good

\*Numbers refer to literature cited.

rooting ability is presented in Table II. Considering all four factors the most promising species in Southwest Texas were *candicans*, *champini*, *cinerea*, and *monticola*. In case of failure to find the ideal stock in the wild, hybridization is a possible solution.

<sup>1</sup>Technical Contribution No. 496, Texas Agricultural Experiment Station.

Each wild plant is considered a separate clonal selection and separate records are kept for each. A preliminary rooting test of about 25 cuttings is given. From these tests, selections are made for a grafting test the following year. Cuttings are used in making the whip grafts. At least 10 grafts are made of each combination about February 1 and buried in moist warm sand until about March 1 when growth begins. They are then lined out 2 inches apart in rows 6 feet apart with the graft union just above the ground level. Then the whole graft is covered with loose earth to 2 inches above the scion. They are kept moist with irrigation down each side of the row. About June 1 the earth is removed to the ground level and scion roots removed as well as sprouts from the stock.

Grafting tests have been conducted over a period of 6 years, 1933 to 1938, inclusive. A total of 512 combinations were used involving 51 stocks. Scions were mostly *vinifera* varieties with particular emphasis on the seedless varieties (Sultanina, Sultanina Rosea, and Monukka).

TABLE II—RELATIVE ROOTING ABILITY OF GRAPE SPECIES

Species	Number Selections	Rooting from Cuttings (Per Cent)		
		Highest	Lowest	Average
Berlandieri.....	23	80	0	20
Candicans.....	14	83	0	31
Champini.....	1	84	40	59
Cinerea.....	2	100	9	55
Cordifolia.....	1	79	0	39
Lincecumii.....	6	43	0	17
Monticola.....	11	58	8	34
Rupestris.....	1	100	92	96
Treleasii.....	6	100	25	52
Labrusca.....	14	100	17	70
Vinifera.....	30	100	18	56

Practically all the *vinifera* varieties and most of the *labrusca* varieties under test at Winter Haven have been grafted on one or more resistant stocks in order to maintain them at the Station. Space does not permit tabulating all the records here, and only the varieties of commercial promise in Southwest Texas are given in Table III. These are the seedless varieties, Sultanina, Sultanina Rosea, and Monukka. Because it usually gives a good take, Black Muscat was added as a check. In Table III results from 1935, 1936, 1937 and 1938 are tabulated using these four varieties.

Black Muscat had a better average take than either of the three seedless varieties. Even with 22354, a *candicans* selection that shows a rooting percentage from its own cuttings of only 16 per cent gave a satisfactory take with Black Muscat. The poor take with 22378, a *monticola* selection, is indicative of the difficulty of rooting this species. In line with the better take the scion to stock ratio is lower, which is indicative of better unions.

Monukka has generally lower percentages of survival and a wider ratio between scion and stock. Dog Ridge appears to be the best stock for Monukka in the nursery.

Sultanina gives even poorer take than Monukka and has a fairly wide scion to stock ratio. Best nursery results appear to be from La Pryor, La Pryor No. 2, and Dog Ridge.

Sultanina Rosea surprisingly does not give the same response as Sultanina. Champanel and Dog Ridge gave the best per cent survival of grafts and La Pryor one of the poorest.

The results to date are, of course, not conclusive. Annual tests have been mostly confined to small numbers due to lack of material and time to do the necessary work. They are indicative of the fact that resistant

TABLE III—GRAFTING TESTS 1935 TO 1938

Stock	Year	Grafts Lined Out	Survival (Per Cent)	Unions			Scion/ Stock Diam. Ratio (Ave.)*
				Smooth	Slight Swelling	Swelled	
<i>Black Muscat</i>							
22354 (Candicans) . . . . .	1935	10	40	3	1	—	1.04
	1938	10	50	4	1	—	1.06
Champanel . . . . .	1935	9	33	2	1	—	0.85
	1936	10	40	4	—	—	1.06
	1938	10	10	1	—	—	1.00
22356 (Candicans) . . . . .	1938	10	40	4	—	—	1.06
22358 (Candicans) . . . . .	1938	10	70	7	—	—	1.00
Dog Ridge (Champini) . . . . .	1935	10	40	2	2	—	0.95
	1936	10	60	5	—	1	1.01
	1938	10	70	5	2	—	1.09
Indian Creek No. 3 . . . . .	1938	10	40	4	—	—	1.00
22378 (Monticola) . . . . .	1938	10	10	1	—	—	1.19
La Pryor . . . . .	1935	10	30	1	2	—	1.11
	1936	10	80	7	1	—	1.12
	1938	10	60	6	—	—	1.19
La Pryor No. 2 . . . . .	1936	10	10	—	—	1	1.00
	1938	10	80	4	4	—	1.21
La Pryor No. 3 . . . . .	1938	10	60	4	2	—	1.11
La Pryor No. 4 . . . . .	1938	10	80	7	1	—	1.10
Leona No. 5 (Candicans) . . . . .	1938	10	70	6	1	—	1.11
Lukfata . . . . .	1936	10	50	1	2	2	1.08
	1938	10	80	6	2	—	1.17
Marguerite . . . . .	1938	10	20	1	1	—	1.02
3309 (Riparia X Rupestris) . . . . .	1938	10	40	3	1	—	1.07
<i>Monukka</i>							
22354 (Candicans) . . . . .	1938	10	40	—	2	2	1.21
Champanel . . . . .	1936	10	10	—	1	—	1.08
Champanel . . . . .	1937	30	20	2	2	2	1.35
	1938	10	20	1	1	—	1.23
22356 (Candicans) . . . . .	1938	10	0	—	—	—	—
Dog Ridge . . . . .	1936	10	50	4	1	—	1.07
	1937	30	40	6	4	2	1.32
	1938	10	50	1	4	—	1.35
Indian Creek No. 3 . . . . .	1938	10	0	—	—	—	—
22378 (Monticola) . . . . .	1938	10	10	—	—	1	1.28
La Pryor . . . . .	1936	10	30	2	—	1	1.18
	1937	30	30	2	4	3	1.26
	1938	10	10	—	—	1	—
La Pryor No. 2 . . . . .	1936	10	40	1	2	1	1.07
	1937	10	40	3	—	1	1.15
	1938	10	80	—	3	5	1.35
La Pryor No. 3 . . . . .	1937	10	30	—	—	3	1.37
	1938	10	40	—	2	2	1.32
La Pryor No. 4 . . . . .	1937	10	70	1	3	3	1.19
	1938	10	10	—	—	1	1.42
Lukfata . . . . .	1938	10	0	—	—	—	—
Marguerite . . . . .	1936	10	0	—	—	—	—
	1937	10	0	—	—	—	—
	1938	10	0	—	—	—	—

\*Calculated from circumference measured at end of one year's growth in nursery.

TABLE III—*Concluded*

Stock	Year	Grafts Lined Out	Survival (Per Cent)	Unions			Scion/ Stock Diam. Ratio (Ave.)*
				Smooth	Slight Swelling	Swelled	
Sultanina							
22354 (Candicans) . . . . .	1935	9	0	-	-	-	-
	1937	50	20	3	5	2	1.27
	1938	10	10	-	-	1	1.25
Champanel. . . . .	1935	10	30	-	3	-	1.10
	1936	10	10	-	1	-	1.15
	1937	60	45	3	7	17	1.28
	1938	10	0	-	-	-	-
22356 (Candicans) . . . . .	1938	10	10	-	-	1	1.36
22358 (Candicans) . . . . .	1938	10	0	-	-	-	-
Dog Ridge. . . . .	1935	10	40	-	-	4	1.18
	1936	10	0	-	-	-	-
	1937	60	22	6	4	3	1.13
	1938	10	30	-	3	-	1.28
Indian Creek No. 3 . . . . .	1935	10	10	-	-	1	1.33
	1936	10	10	-	-	1	1.30
	1938	10	10	-	-	1	1.31
22378 (Monticola) . . . . .	1935	10	0	-	-	-	-
	1936	10	0	-	-	-	-
	1938	10	10	-	1	-	1.27
La Pryor . . . . .	1935	10	50	-	1	4	1.23
	1936	10	10	-	1	-	1.12
	1937	60	35	8	8	5	1.30
	1938	10	70	2	2	3	1.16
La Pryor No. 2 . . . . .	1935	10	50	-	1	4	1.38
	1936	10	40	2	2	-	1.18
	1937	10	50	-	-	5	1.52
	1938	10	40	2	2	-	1.22
La Pryor No. 3 . . . . .	1937	10	10	-	1	-	1.72
	1938	10	50	1	1	3	1.29
La Pryor No. 4 . . . . .	1935	10	20	-	2	-	1.12
	1937	10	30	-	1	2	1.49
	1938	10	10	1	-	-	1.44
23017 (Candicans) . . . . .	1938	10	40	1	1	2	1.16
Lukfata . . . . .	1935	10	10	-	-	1	1.17
	1938	10	0	-	-	-	-
Marguerite. . . . .	1936	10	0	-	-	-	-
	1937	10	0	-	-	-	-
	1938	10	30	1	2	-	1.19
3309 (Riparia X Rupestris)	1938	10	90	2	4	3	1.25
Sultanina Rosea							
22354 (Candicans) . . . . .	1938	10	20	1	-	1	1.24
Champanel . . . . .	1935	10	10	-	-	1	1.22
	1936	10	10	-	-	1	1.09
	1937	30	50	6	6	3	1.39
	1938	10	50	3	2	-	1.41
22356 (Candicans) . . . . .	1938	10	10	-	-	1	1.00
22358 (Candicans) . . . . .	1938	10	20	-	2	-	-
Dog Ridge . . . . .	1935	10	0	-	-	-	-
	1936	10	0	-	-	-	-
	1937	30	53	8	6	2	1.17
	1938	10	30	-	3	-	1.37
Indian Creek No. 3 . . . . .	1936	10	10	-	-	1	1.40
	1938	10	20	1	-	1	1.28
22378 (Monticola) . . . . .	1938	10	0	-	-	-	-
La Pryor . . . . .	1935	10	0	-	-	-	-
	1936	10	0	-	-	-	-
	1937	30	3	-	1	-	1.47
	1938	10	0	-	-	-	-
La Pryor No. 2 . . . . .	1936	10	0	-	-	-	-
	1937	10	0	-	-	-	-
	1938	10	0	-	-	-	-
La Pryor No. 3 . . . . .	1937	10	0	-	-	-	-
La Pryor No. 4 . . . . .	1937	10	10	-	1	-	1.30
	1938	10	0	-	-	-	-
Lukfata . . . . .	1935	10	0	-	-	-	-
	1938	10	40	2	1	1	1.08
Marguerite. . . . .	1936	10	10	-	1	-	0.97
	1937	10	10	-	-	1	1.63
	1938	10	10	-	-	1	1.42

\*Calculated from diam. of

stocks for *vinifera* varieties are possible, to permit their growth in the presence of root-rot. They also show definitely that tests are necessary for each scion variety to determine the most suitable stocks.

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## The Influence of Certain Root-forming Substances in Blueberry Propagation

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## ABSTRACT

This material will be published in full in the May (1939) issue of the Michigan Quarterly Bulletin.

**E**XPERIMENTS were conducted at the South Haven Experiment Station, Michigan State College, during 1937 and 1938 in which hardwood cuttings of the blueberry varieties Rubel, Adams, Cabot, and Pioneer were treated with Hormodin "A" and with Auxilin in 1938 to determine the influence of these materials on (a) the speed of root formation, and (b) the total percentage of rooting. No advantage was apparent from the use of these materials in comparison to untreated cuttings.

## Some Observations on the Propagation of the High-Bush Blueberry<sup>1</sup>

By A. E. STENE, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

**P**REVIEW of recent literature on the propagation of high-bush blueberries by hardwood cuttings reveals certain differences in the recommendations of individual workers. These may be due to variations in approach to the problems involved, in climate, or in the equipment available, and may be of considerable importance from a practical standpoint.

Some time ago two box frames were constructed at the Rhode Island Agricultural Experiment Station in accordance with plans suggested in a special bulletin of the Michigan Station (1). An attempt to root hardwood cuttings in these frames by following methods suggested in the bulletin mentioned was not satisfactory, largely because of heavy inroads of disease on cuttings. Nurserymen and other Rhode Island propagators have also, on various occasions, complained that they were unable to get results similar to those obtained by the Michigan Station.

Recommendations from other experiment stations indicate that the various authors differ in their equipment and methods, and notably, in the type of frame that they advocate, in the rooting media used, and in the different procedures suggested for ventilation and shading. It seemed worth-while to make a preliminary comparison of some of these diverse recommendations under Rhode Island conditions in order to determine whether results would differ to a significant degree.

Accordingly, the two box frames mentioned were set up in the spring of 1938 with cutting trays having hardware cloth bottoms as suggested in the Michigan bulletin. A cold frame section was also fitted up in a similar manner with a tray suspended about 6 inches from the bottom of the frame. Two kinds of rooting media were prepared; namely, all Holland peat, and three-quarters Holland peat and one-quarter sand. Having in mind previous experience with disease, strictly fresh material was used by taking peat from a new bale, and sand directly from a pit. The two box frames had duplicate sections and the cold frame a single section of each rooting medium.

Cuttings were taken the first week in April, kept from drying, and planted within a week. Cuttings of several varieties were available but not in like numbers. The two box frames were planted with all varieties but the cold frame had only four varieties. However, all records have been kept in percentages and it is believed that the figures given are comparable.

Glass sash was kept tightly in place on one box frame until the cuttings began to root. The other box frame, also covered with sash, received some ventilation from the start by raising the sash about 1 inch at the front edge during hot days. No sash was used on the cold frame.

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All frames were shaded by a very coarse burlap, supplemented during the hot part of the day with a lath frame in which the open spaces were approximately equal to the width of the lath.

The cuttings leafed out first in the unventilated box frame, next in the ventilated box frame, and last in the cold frame. Disease appeared in about the same order and was absent in the cold frame for a long time so that the cuttings in this frame at first looked very promising. In the end, however, this frame contained the lowest percentage of rooted cuttings. It is interesting to note that stem rot diseases were most destructive to cuttings in the all-peat media of the sash covered

TABLE I—A COMPARISON OF DISEASE DESTRUCTION AND ROOTING WITH THREE METHODS OF EXPOSURE AND TWO ROOTING MEDIA IN THE THREE FRAMES

Frame	Rooting Medium	Destroyed by Disease (Per Cent)	Rooted (Per Cent)	Rooted in Each Frame (Per Cent)
Box frame, ventilated. . .	All peat	30	45	44
	Peat and sand	20	42	
Box frame, unventilated.	All peat	37	48	32
	Peat and sand	33	16	
Cold frame, no sash. . . .	All peat	10	17	26
	Peat and sand	10	34	

frames, nevertheless this medium produced the larger percentage of rooted cuttings in these frames. In the open frame the sand and peat gave the best results, possibly because the more compact medium retained moisture better under the more extensive evaporation possible in this frame.

The records suggest that the heavy invasion of disease in the covered frames was the chief limiting factor to a satisfactory percentage of rooting, and if the rooting medium can be sterilized, Holland peat in sash covered frames will probably give very satisfactory results. The somewhat lower percentage of disease and higher percentage of rooting in the ventilated frame lends weight to this conclusion. The records also suggest, however, that if a less air-permeable covering, such as sheeting, can be used in a tight-fitting shade frame on a cold frame without sash this equipment also may give better results and may possibly produce cuttings more cheaply than the sash covered frames.

There was a wide variation in the percentage of rooting in the two media of the sash covered frames but, in view of the greater destruction by disease in the unventilated frame, it would seem that the difference in percentage of rooting in these frames can be considered as significant. It suggests that under Rhode Island conditions with less intense sunlight and higher humidity, ventilation is more important than farther inland, as for instance under Michigan conditions.

In common with experiences elsewhere, there was considerable variation in the percentage of rooting of different varieties under similar conditions. Table II presents a record of results with ten different varieties as observed in this experiment.



TABLE II—AVERAGE PERCENTAGE OF ROOTING OF HARDWOOD CUTTINGS OF TEN VARIETIES OF HIGH-BUSH BLUEBERRIES

	Adams	Concord	Dunfee	Grover	Jersey	Katherine	Pioneer	Ran-cocas	Rubel	Wild
Ventilated frame . . .	50	30	44	45	75	32	27	44	72	35
Unventilated frame . .	8	11	50	34	45	28	20	50	37	35
Open cold frame . . . .	21	—	—	54	—	—	9	—	—	19
Average . . . . .	26	21	47	44	60	30	19	47	55	30

While Table II shows a great deal of variation in the percentages under different conditions of rooting, it is believed that the general average under each variety is indicative of its probable response to rooting conditions. Probably no two tests would give exactly the same responses and more conclusive results can be secured only by comparing a great number of rooting tests under identical conditions.

TABLE III—COMPARISON OF AVERAGE MAXIMUM, MINIMUM, AND 1:00 P.M. TEMPERATURES (FAHRENHEIT) ABOVE AND BELOW CUTTING TRAYS IN VENTILATED FRAME

	May			June			July			Season Average
	Maximum	Minimum	1 P.M.	Maximum	Minimum	1 P.M.	Maximum	Minimum	1 P.M.	
Above tray . .	86	44	71	91	56	82	92	65	84	75
Below tray . .	78	45	69	82	55	74	83	63	78	70

Records were kept in the ventilated frame, above and below the cutting trays, of daily maximum, minimum, and 1:00 p.m. temperatures and the results are presented in Table III.

It may be noted from Table III that the temperature ranged uniformly higher above the cutting trays, even though this frame was ventilated during the hot part of the day, a condition definitely contrary to the commonly accepted requirement for successful rooting of cuttings. There appears to be a need for further study of the question of bottom heat in relation to the rooting of hardwood blueberry cuttings. Probably also, the choice of plans for the construction of propagating equipment as well as the operating methods will have to be modified somewhat in accordance with the special requirements under different climatic conditions.

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## Effects of Indole-3-Butyric Acid in the Rooting of Transplanted Pecan Trees

By L. D. ROMBERG and C. L. SMITH, *U. S. Department of Agriculture, Austin, Tex.*

THE fact that nursery-grown pecan trees usually make very little growth the first year or two after transplanting has long been recognized by growers and propagators. Numerous observations have shown that this lack of growth is due largely to the difficulty of reestablishing the root system. This condition is responsible for the loss of many transplanted trees because the weakened trees are more readily affected by sun scald and are more subject to attack by borers than normally vigorous growing trees. Therefore, it is desirable to find some method of overcoming this difficulty in order to reestablish the trees more quickly and to avoid the loss of trees. Previous efforts to facilitate quick reestablishment of transplanted pecan trees have met with little success. Smith and Hamilton (1) pruned the taproots of trees in the nursery in the spring before the trees were dug for transplanting the following winter. This treatment stimulated new root formation in the transplanted trees to a small extent but was of doubtful value as an economic practice since the trees were severely stunted in the year the taproots were cut, and in many cases their root development after transplanting was no better than that of check trees.

For the past few years root-inducing chemicals have been used with success in the rooting of various cuttings (2, 3, 4). In 1936 the authors treated pecan root cuttings with a water solution of indole-3-butyric acid and with a mixture of the chemical in lanolin. The latter was smeared on the bases of the cuttings, or applied in slits or holes made through the bark. With large cuttings the best rooting response occurred where the lanolin mixture was applied in slits or holes made in the roots so that the chemical was in direct contact with the root cortex. With cuttings larger than  $\frac{3}{4}$  inch in diameter little rooting response was obtained where the lanolin mixture was smeared on the bark. The bark of such cuttings is probably too thick to allow ready diffusion of the chemical into the root cortex.

In the winter of 1936-37, roots of nursery pecan seedling trees were treated at the time of transplanting with a mixture of 0.5 per cent indole-3-butyric acid in lanolin. Several methods of application of the lanolin mixture were used, including smearing it on the bark of the laterals and taproots, applying it in slits in the bark of the roots, and putting it in auger holes bored into the roots. Rooting was stimulated in many cases but the results were not conclusive because of the effects of a severe spring and summer drought. The best rooting occurred where the chemical was applied in slits or holes in the roots, and it was indicated that localized treatments were more effective than those which involved large areas. In more comprehensive experiments initiated in February, 1938 in which different concentrations, as well as different carriers of the indole-3-butyric acid were used, all applications were made in holes in the roots.

## METHODS OF PROCEDURE

Comparable lots of 11 trees each were selected for the treatments. Fairly vigorous nursery seedling trees 5 and 7 years old were used. The trees were dug and shipped to the U. S. Pecan Field Station, Brownwood, Texas, where the roots were treated with indole-3-butyric acid, and the trees transplanted under uniform conditions in the usual manner on February 9-11, 1938. One lot of eight trees that were 10 years of age was also treated and transplanted. Treatments were as follows: Lot 1. No treatment, check; Lot 2. 0.5 per cent indole-3-butyric acid in wheat flour dough in holes in taproots and laterals; Lot 3. 0.5 per cent indole-3-butyric acid in lanolin in holes in taproots and laterals; Lot 4. Toothpicks each carrying 0.5 milligram of indole-3-butyric acid in holes in taproots and laterals; Lot 5. Toothpicks each carrying 1 milligram of indole-3-butyric acid in holes in taproots and laterals; Lot 6. Toothpicks each carrying 2 milligrams of indole-3-butyric acid in holes in taproots and laterals; Lot 7. Toothpicks each carrying 4 milligrams of indole-3-butyric acid in holes in taproots and laterals; Lot 8. Toothpicks each carrying 4 milligrams of indole-3-butyric acid in holes in taproots only; Lot 9. Toothpicks each carrying 4 milligrams of indole-3-butyric acid in holes in taproots and laterals, taproots cut to 24 inches in length; and Lot 10. Toothpicks each carrying 4 milligrams of indole-3-butyric acid in holes in lateral roots of trees 10 years old.

The lanolin mixture contained 0.5 per cent of indole-3-butyric acid by weight, the chemical being thoroughly mixed with the lanolin. The dough mixture consisted of 0.5 per cent of indole-3-butyric acid by weight thoroughly mixed with a paste made of wheat flour and distilled water. This mixture was used because it was thought the indole-3-butyric acid would diffuse from it more readily than from the lanolin mixture.

The toothpicks were prepared as follows: the pointed ends of ordinary round toothpicks were cut off leaving the middle portion 4 centimeters long. The desired concentrations of indole-3-butyric acid were prepared in 95 per cent ethyl alcohol and the toothpicks were soaked in these solutions for 24 hours. They were then removed and allowed to dry. In the preparation of toothpicks carrying 4 milligrams of indole-3-butyric acid 1 gram of the chemical was dissolved in 21 milliliters of alcohol. Each toothpick absorbed approximately 0.084 milliliter of the solution.

The toothpicks were used as carriers of the chemical because less time was required to make treatments with these and because there was less waste than in applying lanolin or dough mixtures with a syringe, with consequent lowering of the cost of treatment.

In making the treatments in the taproots holes were bored transversely through the side of the root with an electric drill, using a 7/64 inch bit and allowing the bit to come out about 1 to 1½ inches from where it entered the root. Holes were bored transversely through the lateral roots about ¾ inch from the cut ends. The holes were filled with the mixtures of lanolin or dough by means of a syringe, or with toothpicks which, if necessary, were broken into pieces just long

enough to fill the holes. All lateral roots  $\frac{3}{8}$  inch or more in diameter were treated except in Lot 8 in which only the taproots received the treatment. In cases where the trees had very few lateral roots large enough to treat, a few treatments were made in the taproots at the bases of small laterals. All taproots of the 5- and 7-year-old trees were treated at the ends. In most cases one toothpick 4 centimeters long, or equivalent amounts of lanolin or dough mixture were applied in holes near the ends of the taproots, but the large taproots received two treatments.

Two trees from each treatment were dug on July 7, 1938, and four to six trees from each treatment were dug October 24 to November 3, 1938. Photographs were made of the root systems at the time the trees were dug. The shoot growth of all trees was measured and recorded, and the new roots were counted, measured, and the dry weight determined. The roots from treatments of laterals, sides of taproots, ends of taproots, and other roots not originating directly from points of treatment were kept in separate lots for each tree so as to determine the relative response from the different points of treatment. The averages of these data for the different lots of trees are given in Tables I, II, and III, and photographs of typical root systems showing the rooting responses from some of the treatments are given in Figs. 1 to 6.

## RESULTS

All treatments except those with the dough mixture greatly increased the amount of rooting, as measured by the average dry weight, the number, and the average total length of the roots per tree (see Tables I and II). The average dry weight of the roots from trees treated with the dough mixture was about 43 per cent higher than that from the check trees, but the average number and length of roots per tree were

TABLE I—THE AVERAGE NUMBER AND AVERAGE TOTAL LENGTH OF NEW ROOTS PRODUCED BY TRANSPLANTED PECAN TREES THAT RECEIVED ROOT TREATMENTS WITH INDOLE-3-BUTYRIC ACID AT DIFFERENT CONCENTRATIONS, AND THE AVERAGE NUMBER OF NEW ROOTS PER TREATMENT IN SIDES OF TAPROOTS, AT ENDS OF TAPROOTS, AND IN LATERAL ROOTS

Lot Number and Treatment	Average Number New Roots per Tree	Average Total Length New Roots per Tree (Inches)	Average Number Roots per Treatment		
			In Side of Taproot	At End of Taproot	In Laterals
1. Check. No treatment.	36.00	219.0	—	—	—
2. 0.5 per cent dough mixture	35.33	228.0	3.00	5.00	2.42
3. 0.5 per cent lanolin mixture	65.30	417.3	—	4.75	4.36
4. 0.5-milligram toothpicks.	48.00	380.2	3.25	7.25	2.52
5. 1-milligram toothpicks.	60.00	453.0	7.00	8.85	3.80
6. 2-milligram toothpicks	89.00	580.3	8.00	8.00	10.50
7. 4-milligram toothpicks	66.00	586.0	12.25	7.66	5.84
8. 4-milligram toothpicks, taproot only	96.80	685.8	6.77	8.00	—
9. 4-milligram toothpicks, taproots cut to 24 inches	112.50	852.7	17.00	11.00	8.00
10. 4-milligram toothpicks, 10-year-old trees*	228.33	1465.6	—	—	9.78

\*Lots 1 to 9 were made up of 5- and 7-year-old trees.

TABLE II—THE AVERAGE DRY WEIGHT OF NEW ROOTS PRODUCED PER TREE AND PER POINT OF TREATMENT IN TRANSPLANTED PECAN TREES THAT RECEIVED ROOT TREATMENTS WITH INDOLE-3-BUTYRIC ACID AT DIFFERENT CONCENTRATIONS

Lot Number and Treatment	Average Dry Weight of All New Roots per Tree (Grams)	Average Dry Weight of New Roots per Treatment			Average Dry Weight of Other New Roots* per Tree (Grams)
		In Side of Taproot (Grams)	In Laterals (Grams)	At End of Taproot (Grams)	
1. Check.....	3.85	—	—	—	—
2. 0.5 per cent dough mixture.....	6.65	1.53	0.49	0.86	1.87
3. 0.5 per cent lanolin mixture.....	10.58	—	0.86	1.48	2.26
4. 0.5-milligram toothpicks.....	11.99	3.20	0.53	2.00	3.74
5. 1-milligram toothpicks.....	14.56	4.32	1.06	1.40	3.80
6. 2-milligram toothpicks.....	12.07	2.32	1.56	1.05	1.90
7. 4-milligram toothpicks.....	16.13	5.66	0.70	0.80	2.37
8. 4-milligram toothpicks, taproot only.....	19.14	2.57	—	1.48	4.71
9. 4-milligram toothpicks, taproots cut to 24 inches.....	30.29	5.40	2.04	4.64	1.94
10. 4-milligram toothpicks, 10-year-old trees†.....	37.17	—	1.48	—	2.56

\*Roots not originating directly from points of treatment.

†Lots 1 to 9 were made up of 5- and 7-year-old trees.

about the same. In all cases greater rooting response was obtained from the lots of trees treated with toothpicks carrying 4 milligrams of indole-3-butyric acid than from other treatments, except that lot 6, which was treated with 2-milligram toothpicks, showed a greater total number of roots per tree than lot 7, which was treated with 4-milligram toothpicks (see Table I). The greatest average dry weight of roots per tree for the 5- and 7-year-old trees was from treatments with 4-milligram toothpicks in trees with the taproots cut to 24 inches in length. As will be noted from Fig. 6, these trees rooted profusely at the lower ends of the taproots. There was much less rooting at these points on trees with taproots 30 to 36 inches in length, regardless of the

TABLE III—THE AVERAGE AMOUNT OF INDOLE-3-BUTYRIC ACID USED PER TREE AND THE AVERAGE DRY WEIGHT OF NEW ROOTS PRODUCED PER MILLIGRAM USED IN THE TREATMENT OF ROOTS OF PECAN NURSERY TREES WITH INDOLE-3-BUTYRIC ACID AT DIFFERENT CONCENTRATIONS

Lot Number and Treatment	Average Amount of Indole-3-butyric Acid Used per Tree (Milligrams)	Average Dry Weight* of Roots Produced	
		Per Tree (Grams)	Per Milligram Indole-3-butyric Acid Used (Grams)
2. 0.5 per cent dough mixture.....	0.43	2.80	6.51
3. 0.5 per cent lanolin mixture.....	0.33	6.73	20.39
4. 0.5-milligram toothpicks.....	1.60	8.14	5.08
5. 1-milligram toothpicks.....	3.26	10.71	3.28
6. 2-milligram toothpicks.....	5.85	8.22	1.40
7. 4-milligram toothpicks.....	15.28	12.28	0.80
8. 4-milligram toothpicks, taproot only.....	22.90	15.29	0.67
9. 4-milligram toothpicks, taproots cut to 24 inches.....	19.60	26.44	1.35

\*The average dry weight of roots produced per tree after subtracting the average dry weight of roots produced by check trees.

treatment. This difference in rooting at the end of the taproots accounts largely for the increase in average dry weight of roots per tree in this lot as compared with the other trees treated with 4-milligram toothpicks. The 5-year-old trees rooted better at the ends of the 24-inch taproots than did the 7-year-old trees, but there was little difference in the rooting response at the ends of the taproots in trees of the two different ages where the taproots were left 30 or 36 inches long. The rooting response was also greater in 5-year-old trees than in 7-year-old trees from treatments in the sides of the taproots. This probably was due to the absence of many large lateral roots on the 5-year-old trees and to their presence on 7-year-old trees. In both 5- and 7-year-old trees the rooting of laterals was stimulated by treatments in the sides of the taproots, which indicates that the indole-3-butyric acid diffused into these lateral roots from the taproots. This stimulation at a distance was especially evident in 7-year-old trees as is shown in Fig. 5, right. It is also reflected in the high average dry weight per tree of roots other than those originating directly from points of treatment in trees which were treated in taproots only (see Table II, Lot 8, column 6).

For each treated lot the greatest average number of roots per treatment was obtained from applications of the indole-3-butyric acid at the lower ends of the taproots (see Table I), except that in Lot 7 the greatest development was from treatments in the sides of the taproots. The lowest average number of roots per

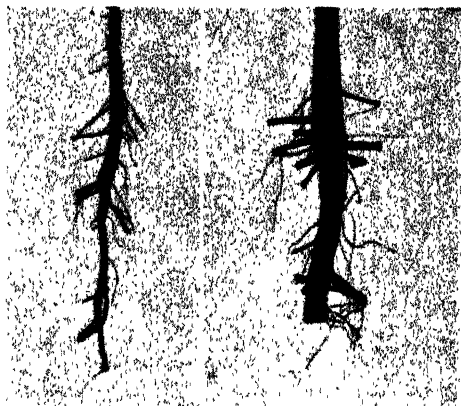


FIG. 1. Typical rooting response during the first season's growth of transplanted pecan trees. Untreated check trees. Left, 5-year-old tree; Right, 7-year-old tree.



FIG. 2. Typical rooting response during the first season's growth of transplanted pecan trees that had their roots treated with 0.5 per cent indole-3-butyric acid in lanolin. Left, 5-year-old tree; Right, 7-year-old tree.

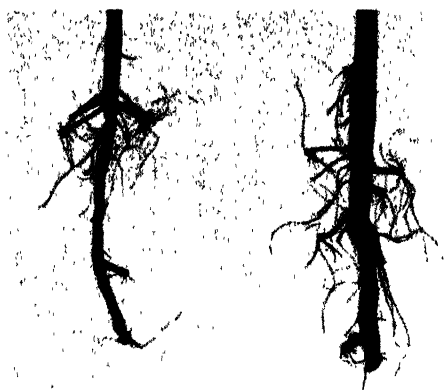


FIG. 3. Typical rooting response the first season after transplanting of pecan trees that received root treatments with indole-3-butyric acid in toothpicks at a concentration of 2 milligrams per toothpick. Left, 5-year-old trees; Right, 7-year-old tree.

Most of the trees in the experiment were attacked by flat-headed apple tree borers and the shoot growth was thereby affected to a considerable extent. For this reason the data for total shoot growth are

treatment was obtained from treatments in lateral roots, except in Lot 6.

The rooting response was excellent in the lateral roots of 10-year-old trees treated with 4-milligram toothpicks. These trees produced an average of 228 new roots per tree with an average total length of 1,465 inches, which was nearly twice as great as the average for the best lot of 5- and 7-year-old trees. The average dry weight of the roots per tree was also higher, and the average total length of new shoot growth per tree was 322 inches.

It was not determined whether or not a direct correlation of shoot growth and rooting response is to be expected the first season after transplanting the treated trees.

The average amount of indole-3-butyric acid used per tree was calculated as well as the average dry weight of the new roots produced per milligram of the chemical used. In making the latter calculations the average dry weight of the roots produced by the check trees was subtracted from the averages for the different lots of treated trees, and the resulting figures were then divided by the average number of



FIG. 4. Typical rooting response the first season after transplanting of pecan trees that received root treatments with indole-3-butyric acid in toothpicks at a concentration of 4 milligrams per toothpick. Left, 5-year-old tree; Right, 7-year-old tree.

milligrams of indole-3-butyric acid used per tree. The data are given in Table III and show that the average dry weight of roots produced per milligram of indole-3-butyric acid used was in general inversely proportional both to the concentration and to the average amount used per tree.

The number of treatments per tree varied greatly for the same concentration of indole-3-butyric acid and consequently the total amount per tree varied to about the same extent, but there was no direct correlation of the rooting responses of individual trees with the total amount used, or with the concentration. In general, however, the trees treated with the toothpicks carrying 4 milligram of the indole-3-butyric acid gave better rooting responses than trees treated with the lower concentrations. In no case was the best rooting response from treatments with a lower concentration equal to the best response from treatments with the 4-milligram toothpicks. There was more callus formation from treatments with the higher concentrations. While it is true that trees treated with the higher concentrations also received greater amounts of the indole-3-butyric acid, it is believed the concentration is fully as important in inducing root formation as is the total amount used per tree.

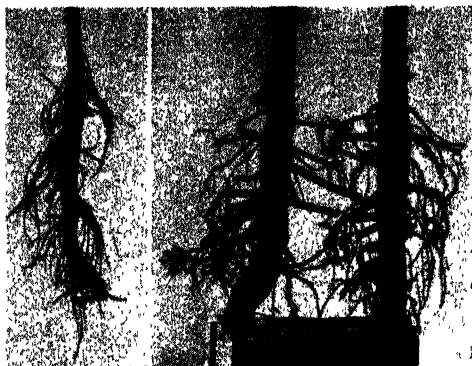


FIG. 5. Typical rooting response the first season after transplanting of pecan trees that received taproot treatments with indole-3-butyric acid in toothpicks at a concentration of 4 milligrams per toothpick. Left, 5-year-old tree; Right, 7-year-old trees. Note the large number of roots formed from points of treatment in the taproot of the 5-year-old tree as compared with very few from corresponding points of treatment in the taproots of the 7-year-old trees. However, the rooting of the lateral roots of the latter trees has been stimulated by the diffusion of the indole-3-butyric acid from the taproots.

## DISCUSSION

The data show rooting responses from all treatments used, but the higher concentrations gave the greatest responses. The average dry weight of new roots per tree resulting from treatments with the dough mixture was only 43 per cent greater than that of check trees, while the average dry weight of new roots of trees treated with the lanolin mixture was almost three times as great as that of check trees. The lanolin and dough mixtures contained the same concentration of indole-3-butyric acid (0.5 per cent). It is thought that the indole-3-butyric acid diffused from the dough mixture much more rapidly than from the lanolin and thus a great portion of it was lost by diffusion into the soil



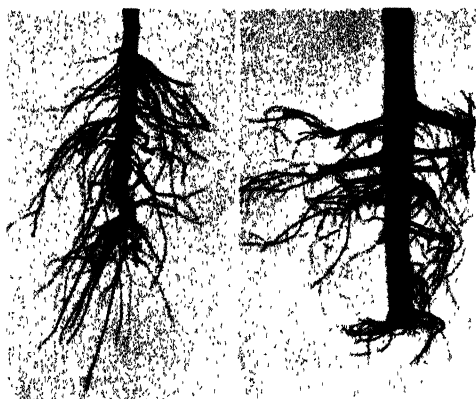


FIG. 6. Typical rooting response the first season after transplanting of pecan trees that received root treatments with indole-3-butyric acid in toothpicks at a concentration of 4 milligrams per toothpick. The taproots of these trees were cut to 24-inch lengths. Left, 5-year-old tree; Right, 7-year-old tree. Note the greater amount of rooting at the end of the taproot in the 5-year-old tree than in the 7-year-old tree.

solution. This could account for the lesser response from the dough mixture.

The concentration of 4 milligrams of indole-3-butyric acid per toothpick was more effective in causing callus formation and rooting than any of the lower concentrations. Many of the roots resulting from treatments with this concentration in the sides of taproots were large in diameter, non-cylindrical, and non-uniform in shape and had a lower percentage of dry matter than roots arising from the treated lateral roots, whereas roots from treatments with the lower concentrations of indole-3-butyric acid in the

sides of taproots were cylindrical and more uniform in shape. The greater stimulation of root formation from the higher concentration or greater amount of the indole-3-butyric acid probably induced a condition of forced growth of the roots, whereas with the lesser concentrations the rate of root growth was more nearly normal.

The data in Table II show that in all lots where treatments were made in the sides of taproots the greatest average dry weight of roots per treatment was produced. This is due largely to the profuse rooting of the 5-year-old trees from these taproot treatments, since the 7-year-old trees showed little or no rooting directly from the points of treatment in the sides of the taproots. The 7-year-old trees had a greater number of large lateral roots than the 5-year-old trees and most of these laterals rooted profusely, indicating a diffusion of the indole-3-butyric acid from the taproots to the laterals. This comparative rooting response of the 5- and 7-year-old trees is illustrated in Fig. 5. It should also be pointed out that in a number of instances roots originating from treatments in the sides of taproots of 7-year-old trees died before the trees were dug in October, whereas in no case were any of these roots dead on 5-year-old trees. This condition indicates a dominance of the large lateral roots over the taproot so far as new root formation and growth are concerned.

It is particularly significant that the trees with taproots cut to 24 inches in length and treated with 4-milligram toothpicks rooted better than similar trees with normal length taproots of 30 to 36 inches. The increased rooting was due to the greater response at the ends of the

short taproots as is shown by a comparison of Figs. 4 and 5 with Fig. 6. The soil to which all trees in the experiment were transplanted is heavy clay, and it is thought that the lesser rooting response at the ends of the long taproots may have been due to lack of aeration, lower temperature, or other unfavorable soil conditions. However, if trees with 24-inch taproots can be successfully transplanted as is indicated, it will materially reduce the cost of transplanting because of the large saving in the labor of digging trees in the nursery and of digging holes for transplanting.

Since it has been the general experience of pecan growers and nurserymen that old nursery trees are hard to transplant, the rooting response of the 10-year-old trees in this experiment is significant. There is a good demand for trees of large size for lawn plantings or home orchards, and the present results indicate that they can be successfully and economically transplanted by treating the roots with indole-3-butyric acid.

A comparison of the methods used for the application of the indole-3-butyric acid to large cuttings or to roots of transplanted pecan trees, shows the toothpick method to be more economical of material and time than the others tried. At least 25 per cent of lanolin or dough mixture is lost during application with a syringe, whereas there is no significant loss when the toothpicks are used. The average cost per tree of the indole-3-butyric acid treatment with the 4 milligram toothpicks varied from 3.75 to 5.72 cents. Treatment with similar concentrations of the lanolin or dough mixtures would have cost at least 25 per cent more due to the unavoidable loss of the mixtures during their application.

#### SUMMARY

1. Roots of comparable lots of pecan nursery seedling trees, in most cases 5- and 7-years old, were treated with indole-3-butyric acid in toothpicks each carrying 0.5, 1, 2, and 4 milligrams per toothpick, and in lanolin and in wheat flour dough at a concentration of 0.5 per cent by weight.

2. Greater rooting response was obtained from treatments with toothpicks each carrying 4 milligrams of indole-3-butyric acid than from treatments at lower concentrations, although rooting was stimulated by treatments at all concentrations used.

3. The 5-year-old trees rooted better than 7-year-old trees when treatments were made in the sides of taproots.

4. Evidence of the diffusion of the indole-3-butyric acid from taproots to adjacent lateral roots was indicated by the great rooting response of these laterals.

5. Trees with taproots cut to 24 inches in length and treated with toothpicks each carrying 4 milligrams of indole-3-butyric acid showed greater rooting response at the ends of the taproots than did similar trees with taproots 30 to 36 inches long. It is thought that adverse temperatures or soil conditions below the 24-inch level inhibited the root formation at the ends of the longer taproots.

6. The average dry weight of roots produced per tree per milligram of indole-3-butyric acid was in general inversely proportional both to

the concentration and to the average amount used per tree. In the experiments the trees treated with the higher concentrations also received greater amounts of the chemical.

7. The rooting response of 10-year-old nursery pecan trees treated with toothpicks each carrying 4 milligrams of indole-3-butyric acid indicates that trees of this age may be successfully and economically transplanted by treating the roots with this chemical.

8. A comparison of toothpicks, lanolin, and wheat flour dough as carriers of the indole-3-butyric acid in the treatment of the roots of pecan trees shows the use of the toothpicks to be more economical since less time and material are required than in making treatments with lanolin or dough mixtures with a syringe. The loss by the latter method is 25 per cent or more.

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# Effect of Indoleacetic Acid on the Growth of Some Crop Plants

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IT is known that indoleacetic acid and some other growth substances can alter the growth rate of roots and shoots (5, 8, 9, 10, 12), affect the morphological and histological development (2, 3, 4), and control to some extent the transfer of certain solid substances (6) within plants. It has also been reported (1, 5, 11) that the application of small amounts of indoleacetic acid stimulated the growth of some plants. The substance was applied to seeds before planting, in the case of some experiments where increased growth was reported, while in other cases it has been used as a lanolin paste on well developed plants.

The present experiments were undertaken to study the effect of indoleacetic acid when applied as a spray and when dissolved in water with which the plants were irrigated. These experiments were conducted in the field and also under greenhouse conditions.

## EXPERIMENTS CONDUCTED UNDER GREENHOUSE CONDITIONS

In preliminary experiments succulent plants such as beans, marigold, coleus, and four o'clocks were sprayed with aqueous solutions made up of 10 milligrams of indoleacetic acid per liter, the leaves curled and the stems and petioles became slightly bent within  $\frac{1}{2}$  hour to 1 hour following treatment. This response was temporary and as the treated plants recovered quickly, they could not be distinguished from untreated plants within 24 hours after treatment. Aqueous solutions made up of 300 or more milligrams of indoleacetic acid caused extreme bending and distortion of the leaves, petioles and stems of succulent plants. Response to these more concentrated solutions generally reached a maximum within 2 hours after treatment and the plants remained noticeably bent and distorted for 2 or 3 days following treatment.

It was evident from these experiments that (a) indoleacetic acid penetrated the outer cells of succulent plants rapidly when applied in the form of a spray, (b) that the effect was only temporary, the magnitude of the response and time required for recovery depending upon the concentration of the solution used over a range of 1 to 300 milligrams per liter.

Further experiments were conducted using various kinds of oil as a carrier in an effort to decrease the rate at which the indoleacetic acid diffused into the plants and thus prolong the effect obtained when low concentrations were applied. Corn oil, cotton seed, paraffin, and machine oil were not effective in this respect as the time required for plants to respond to equal amounts of acid carried either in water or the different oils was approximately the same. Plants treated with oil mixtures recovered in approximately the same period as those treated with aqueous solutions of the same concentration.

The following experiments were then conducted to determine if the growth of some plants was affected by a general and rapid absorption of various amounts of indoleacetic acid through the epidermis.

Marigold plants grown in quartz sand with complete nutrient (7) were selected for size and uniformity. They were divided into five groups of 50 plants each. The first group was harvested as initial controls by determining the fresh weight of the tops and roots separately, and then recording weight of solid matter after the tissue had dried for 24 hours at 80 degrees C in a well ventilated oven.

Pots containing individual plants of the remaining groups were arranged systematically over a bench so that each group was subjected to the same environmental conditions. The individual plants of group 2 were then sprayed every other day with a freshly prepared aqueous solution made up of 10 milligrams of indoleacetic acid per liter. Plants of groups 3 and 4 were sprayed in the same manner with solutions containing 100 and 300 milligrams per liter respectively, while group 5 was sprayed with water and used as a control.

Within 1 hour after treatment the plants showed a definite response to all concentrations used. The response was very pronounced in the case of those plants treated with the strongest concentration; but all plants recovered within 24 to 36 hours. They became slightly less sensitive to indoleacetic acid spray as evidenced by the amount of bending during an 8-day period in which they were treated on every other day.

Although the leaves and petioles of those plants that were sprayed with the stronger concentration became severely curled and bent following treatment, this condition did not appreciably affect the fresh weight of the plants, Table I. The height of those plants sprayed with a solution containing 300 milligrams was less and the diameters of the upper half of the stems were slightly greater than those of control plants.

A similar experiment was carried out using kidney bean plants as experimental material. The plants were grown in quartz sand with complete nutrient and selected for size and uniformity when about 6 to 8 inches high. They were divided into five groups of 50 plants each, one group harvested as an initial control, and the individuals of the remaining groups were distributed evenly on a bench as previously described. The respective groups were then sprayed every other day with aqueous solutions containing 10, 100, and 300 milligrams of indoleacetic acid per liter. Control plants were sprayed with water. After an 8-day period of treatment the plants were washed free from sand, and the fresh and dry weight determined.

TABLE I—EFFECT OF INDOLEACETIC ACID SPRAY ON FRESH WEIGHT AND HEIGHT OF MARIGOLD AND BEAN PLANTS (FIGURES ARE BASED ON A TOTAL OF 50 PLANTS)

	Controls	10 Mg. per Liter	100 Mg. per Liter	300 Mg. per Liter
Wet weight marigold plants. . .	111	114	114	109
Average height marigold plants. . .	12.4	12.9	11.9	11.0
Wet weight bean plants . . . . .	1061	1099	932	786
Dry weight bean plants . . . . .	190	198	197	150

Plants sprayed with a solution containing 10 milligrams of acid per liter showed only a slight response and recovered within 24 hours. Those treated with 100 milligrams per liter showed a more marked response but recovered in between treatments while the leaves and petioles of those sprayed with a solution containing 300 milligrams per liter became severely bent and curled and failed to recover between treatments. Table I shows that the fresh and dry weights of the plants were not appreciably affected by concentrations from 10 to 100 milligrams of acid per liter, and that they were definitely depressed by the use of 300 milligrams per liter.

#### EFFECT OF SPRAYING SEEDS AND PLANTS GROWN UNDER FIELD CONDITIONS WITH SOLUTIONS OF INDOLEACETIC ACID

Although indoleacetic acid failed to stimulate the growth of plants under greenhouse conditions, it was considered of interest to determine the response when the plants were grown under a more favorable environment in the field.

Calaprove kidney beans, Long's Champion Yellow Dent Corn, Richland oat, and soybean plants of Mammouth Yellow variety were used as experimental material. Plots were laid out 41 x 76 feet and these were divided into 50 adjacent squares, leaving a 3-foot border around the entire plot.

A plot of this design was used for each individual experiment and the various treatments were then applied to plants growing in squares scattered throughout the plot so that each treatment was repeated 10 times, and occurred once in each row and once in each column of squares. A hand planter was used in planting and rows were spaced 8 or 10 inches apart.

The following methods of treatment were used, (a) indoleacetic acid was mixed in corn oil so as to make concentrations of 10, 50, 100, and 300 milligrams per liter of oil. In some cases, these mixtures were then sprayed on once when the plants were 3 to 4 inches above the ground level, while in other cases the plants were sprayed repeatedly at 3 or 4 day intervals. (b) Aqueous solutions of indoleacetic acid were sprayed on plants in the same concentrations as used in the case of oil sprays. (c) Oil and aqueous solutions of indoleacetic of the same concentrations as mentioned above were sprayed on seeds before planting.

In all experiments the plants were grown to maturity. They were then harvested by severing the stems approximately 1 inch above the soil level, and the fresh weight of the tops collected in this manner from each square, was recorded.

The leaves of oat, and the leaves and petioles of kidney bean, and soybean plants became noticeably bent and distorted within 1 to 3 hours after they were sprayed with either oil or water solution containing 300 milligrams of indoleacetic acid per liter, but this condition was only temporary as the plants recovered and the leaves became oriented within 24 hours after treatment. This response was not apparent in the leaves of plants sprayed with lower concentrations of indoleacetic acid, and in the case of corn plants the leaves were not affected by aqueous solutions containing 300 milligrams of indoleacetic

acid per liter. As the plants matured they became less sensitive, as evidenced by the response following treatment.

The height and general appearance of the plants studied was not affected by the spraying and the fresh weight of plants sprayed once was likewise unaffected. The average fresh weight of bean plants sprayed with aqueous solutions at 3-day intervals for 9 days was slightly greater than that of control plants, Table II, but an analysis of variance of these data showed the differences to be insignificant with respect to variation between replicate treatments.

Seeds of oats and beans sprayed with oil or aqueous solutions of indoleacetic acid germinated during the same interval of time, as did untreated seeds, and at the time of harvest there were no significant differences between the time of fruiting or fresh weights of treated as compared to those of control plants.

#### IRRIGATION EXPERIMENTS

Marigold of the Guinea Gold variety grown in clay pots were selected for size and uniformity when the plants were approximately 5 inches tall. They were divided into five groups of 20 plants each. The first group was harvested as an initial control and the remaining were

TABLE II—EFFECT OF INDOLEACETIC ACID SPRAY ON THE FRESH WEIGHT OF BEAN PLANTS GROWN UNDER FIELD CONDITIONS. DIFFERENCES BETWEEN TREATMENT ARE NOT STATISTICALLY SIGNIFICANT (FIGURES REPRESENT GRAMS PER 100 PLANTS)

Plot	Controls	10 Mg. per Liter	50 Mg. per Liter	100 Mg. per Liter	300 Mg. per Liter
1	5641	5184	5881	6547	7423
2	5728	4858	5692	6082	5528
3	5684	4936	6078	6679	5083
4	5856	6049	5413	5521	4431
5	4911	6261	6138	4620	5861
6	4683	5061	6199	5357	6006
7	5341	6074	5640	7421	5364
8	5529	6609	5470	5806	5362
9	6382	5872	6203	6547	6419
10	5674	5493	6387	5928	6421
Total	55429	56397	59101	60508	57898

planted in well mixed soil contained in 2-gallon, glazed, earthen-ware crocks with suitable drainage. The crocks were arranged in the field so that there was a 4-foot space between them to eliminate shading effects. The respective groups were then watered on alternate days with tap water containing 0.01, 0.1, and 1.0 ppm of indoleacetic acid. The final lot was used as a control and watered at the same intervals with tap water.

The treatments had no noticeable effect on the time of flowering. At the end of 30 days the plants were harvested, the stems severed at the soil level, and the wet weight of the tops recorded. Table III shows that concentrations up to 0.1 ppm had no appreciable effect while 1 ppm caused a slight depression in fresh weight.

A similar experiment was conducted using Black Valentine beans as experimental material. Twelve seeds were planted in soil contained

in each of the crocks, and after germination two uniform plants were selected for treatment. There were 40 plants in each group and they were watered on alternate days with tap water containing 0.001, 0.01, and 1 ppm of indoleacetic acid. One group used as a control was given tap water.

There was no noticeable difference in the time required for flower production by plants receiving the various treatments, but those given 1 ppm grew somewhat more vigorously than did the control plants. After 3 weeks the plants were harvested and the fresh weight of the tops determined. It is evident from Table III that 0.01 and 1 ppm of

TABLE III—EFFECT OF IRRIGATING MARIGOLD AND BEAN PLANTS WITH TAP WATER CONTAINING DIFFERENT AMOUNTS OF INDOLEACETIC ACID (FIGURES REPRESENT AVERAGE FRESH WEIGHT IN GRAMS OF TOPS OF 20 AND 40 PLANTS RESPECTIVELY)

Plant	Controls	0.01 Ppm	0.1 Ppm	1.0 Ppm
Marigold	143	142	139	113
		0.001 Ppm	0.01 Ppm	1.0 Ppm
Bean	40.2	44.9	48.0	50.9

indoleacetic acid caused a slight increase in fresh weight while 0.001 ppm had no appreciable affect.

In general, it is concluded from these experiments that when indoleacetic acid was applied to the surface of succulent plants as a fine aqueous or oil spray, it quickly penetrated the walls, and possibly the protoplasts, of at least the epidermal cells. A very definite bending, and curling occurred in the treated parts which was possibly the result of a rapid and uneven enlargement of the outer cells. This effect was temporary, as the cells apparently recovered their original size and shape. They remain sensitive to the stimulus although it was applied repeatedly, but the sensitivity decreased as the plants grew older, possibly because of the greater amount of lignified tissue formed during ageing which caused the plants to become less flexible.

In previous experiments (5) it was found that indoleacetic acid, when applied to the cut surface of decapitated bean plants, stimulated the rate at which they synthesized solid matter. The stimulating effect was clearly evident when the development of new leaves was prevented following treatment, by removing the axillary buds from control as well as treated plants. The present experiments, however, show that when indoleacetic acid was applied to the surface of the entire above ground portion of plants it had no appreciable effect on the amount of solid matter synthesized during a given period of time, except when repeated applications of very concentrated solutions were used, and then a depression of growth was noted.

### CONCLUSIONS

The leaves, petioles and stems of some succulent plants became bent and curled within a few hours after they were sprayed with aqueous solutions of beta indoleacetic acid, indicating a very rapid absorption.



Plants treated in this way recovered rapidly, and in most cases could not be distinguished from untreated plants within 36 hours after treatment.

Aqueous solutions of indoleacetic acid containing 300 milligrams per liter repressed the growth of bean plants that were grown in a greenhouse and sprayed with the solution. Weaker solutions had little effect on their growth. Solutions containing from 10 to 300 milligrams of indoleacetic acid had little effect on the growth of marigold plants although marked bending and curling of the leaves occurred following repeated treatments.

Various amounts of indoleacetic acid dissolved in oil or water and sprayed on oat and bean seeds that were later planted in the field, had no effect on their germination or the fresh weight of the tops at the time of fruiting. Indoleacetic acid had no appreciable effect upon the growth of corn, bean, oat, or soybean plants that were grown in the field, and sprayed with solutions containing this substance.

The fresh weights of the tops of bean plants grown out of doors and irrigated with water containing 0.01 and 1.0 ppm indoleacetic acid were slightly greater than those of control plants. The fresh weights of the tops of marigold plants irrigated with water containing 0.01 ppm of indoleacetic acid were not affected, but were repressed when a solution containing 1.0 ppm was used.

Indoleacetic acid had no effect upon the time of flowering of any of the plants studied.

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# Experimental Production of Winter Injury to the Trunks of Apple Trees by Applying Nitrogenous Fertilizers in the Autumn<sup>1</sup>

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A TYPE of winter injury to the trunks of apple trees, which was first noted in 1936 at Wolfeboro, New Hampshire, in an orchard of mature McIntosh trees under sod culture, is under investigation at the New Hampshire Station. This injury occurred on young trees, or on mature trees which had borne a heavy crop in 1935, and in practically every case on trees which had been fertilized in the fall with some form of available nitrogen. A description of the injury and a discussion of its occurrence in the field in relation to fall fertilization has been published by Rawlings and Potter (1).

In the fall of 1936, 63 small Baldwin trees having trunk diameters ranging from 1½ to 2 inches and situated in the "twenty-six" block of the University of New Hampshire orchard, were divided into seven plots of nine trees each on the basis of similarity in size, vigor and situation. One of the nine trees in each block was left without fertilizer and on four different dates during the autumn one tree was fertilized with 1 pound of cyanamid and one with 1¼ pounds of sulphate of ammonia. Out of the seven trees treated with sulphate of ammonia on October 14, two died during the following season, showing symptoms similar to those described in the paper previously cited; two more showed the same type of trunk injury but survived; one showed some loosening of the bark and the other two were uninjured. Only one of the trees fertilized with cyanamid on the same date showed typical injury. The control trees and those fertilized on the other dates with cyanamid or sulphate of ammonia showed no injury.

Somewhat similar tests were made with mature trees, but without producing the trouble. Four McIntosh trees in the University orchard, 14 in the orchard of Gowen Brothers at Stratham, New Hampshire, 16 McIntosh and 10 Delicious trees in the orchard of Albion Emerson at Hampstead, New Hampshire, were treated about the middle of October by applying from 4 to 16 pounds of cyanamid to an area of 400 square feet of soil surrounding the trunk. In ordinary orchard practice, 4 pounds is the maximum recommended on this area. Some of the trees were left in the orchard. Others were cut down at various dates during the winter, the trunks sawed into sections with a band saw, and similar pieces of fertilized and control trees subjected artificially to temperatures ranging from 0 to -38 degrees F. Microscopic examination a month or more after freezing failed to show any consistent difference in injury which could be ascribed to the fertilizer treatment.

<sup>1</sup>Scientific Contribution No. 71, New Hampshire Agricultural Experiment Station.

On each of four dates, December 23, January 15, February 25 and April 2, samples for chemical analysis were taken of roots, of bark of the trunk and of bark of the scaffold branches. One set of duplicate samples represented a tree that had received 16 pounds of cyanamid and another the unfertilized control. The roots used were all about 5 millimeters in diameter and taken at a distance of approximately 4 feet from the trunk. The whole bark was used, including some suberized and non-living tissue adhering to the outer cortex. Sampling necessitated removal and successive samples had to be taken from different individual trees. These have been analyzed for total and soluble nitrogen. The data, which are in each case averages for the two duplicate samples, are given in Table I. It will be noted that although there was an appreciable increase in nitrogen content of the roots, no significant differences occurred in the bark.

TABLE I—NITROGEN AS PER CENT OF THE DRY WEIGHT (1936-37)

Orchard	Date	Treatment	Roots		Bark of			
			Soluble Nitro- gen	Total Nitro- gen	Trunk		Limbs	
					Soluble Nitro- gen	Total Nitro- gen	Soluble Nitro- gen	Total Nitro- gen
Emerson orchard ..	December 23	Check	.106	0.535	.026	0.763	.032	0.756
		High nitrogen*	.166	0.770	.030	0.789	.032	0.750
Gowen orchard .	January 15	Check	.057	0.380	.022	0.628	.028	0.662
		High nitrogen*	.119	0.445	.021	0.558	.030	0.612
Gowen orchard ..	February 25	Check	.050	0.356	.021	0.566	.028	0.595
		High nitrogen*	.075	0.374	.020	0.542	.029	0.535
Gowen orchard.	April 2	Check	.052	0.371	.019	0.496	.026	0.643
		High nitrogen*	.108	0.461	.022	0.536	.025	0.537

\*16 pounds cyanamid.

Subsequent to laying out the experimental plots in the fall of 1936, another orchard was discovered in which this type of injury had occurred. Here a part of the trees fertilized in the fall of 1935 had borne fruit and a part had not. The injury occurred only on those which had produced a crop during the preceding season. None of the trees used in the experiments of 1936-37 had borne heavily in 1936. This may well account for the lack of injury.

Accordingly, in the fall of 1937, 44 mature McIntosh trees in the "back field" orchard at the University of New Hampshire were fertilized with from 4 to 50 pounds of cyanamid per tree or with an equal quantity of sulphate of ammonia. All of these trees had borne heavily in 1937.

At monthly intervals, samples for histological study were taken from the trunks of the trees in each treatment. Microscopical examination failed to disclose any difference in the tissues that could be ascribed to the fertilizer. Again samples for chemical analysis were taken at intervals throughout the winter. A tool had been adapted to the purpose of securing discs of bark from the trunks and made it possible on successive dates to use composite samples from the same trees. Three series

were used, one consisting of seven controls not fertilized, the second of seven trees treated with from 20 to 50 pounds of cyanamid per tree, and the third of seven trees treated with equal amounts of sulphate of ammonia. Roots were taken just as in 1936-37, but all dead tissue was removed from the bark and only the living phloem and cortex included in the sample.

The data, given in Table II, show that the sulphate of ammonia increased the nitrogen content of the roots, but just as in the previous season, there was no significant change in composition of the bark.

TABLE II—NITROGEN AS PER CENT OF THE DRY WEIGHT (1937-38)

	Treatment	Roots		Trunk (Bark)	
		Soluble Nitrogen	Total Nitrogen	Soluble Nitrogen	Total Nitrogen
December 16.	Check	0.110	0.528	.042	0.650
	Cyanamid	0.142	0.508	.042	0.648
	Ammonium sulphate	0.339	0.792	.042	0.609
February 3	Check	0.280	0.728	.040	0.626
	Cyanamid	0.157	0.530	.036	0.618
	Ammonium sulphate	0.370	0.800	.046	0.612
April 7	Check	0.151	0.604	.036	0.637
	Cyanamid	0.175	0.628	.036	0.592
	Ammonium sulphate	0.496	1.121	.032	0.608
May 20	Check	0.318	0.847	.045	0.584
	Cyanamid	0.187	0.610	.048	0.614
	Ammonium sulphate	0.606	1.176	.052	0.616

In spite of the fact that neither artificial freezing, chemical analysis or microscopic examination revealed any change in the tissues of the trunks of the fertilized trees, it was noted in January that in taking samples from certain trees for histological examination, the bark did not adhere to the wood. On February 3, the bark had definitely loosened from the trunks of four trees, each of which had been treated with 24 pounds or more of ammonium sulphate. On this date a discoloration was observed in the region near the cambium, and was recorded a day or two later by means of Agfa color photographs. As the season progressed this injury developed the distinctive symptoms observed in the injured orchards in 1936 and described by Rawlings and Potter (1). These have been recorded by means of color photographs, and include chlorosis of the leaves, death and disintegration of all the tissues of the bark, and a purplish discoloration of the wood. The characteristic brownish yellow color of the foliage observed on many of the trees in 1936 developed on three of the trees which were nearly completely girdled.

Thus there was produced on each tree receiving 30 pounds or more of ammonium sulphate, an injury distinctive in character and exactly similar to that observed in the field in 1936. Trees receiving no fertilizer, or smaller amounts of ammonium sulphate, or trees fertilized with cyanamid were not affected. One of four trees that received 24 pounds of ammonium sulphate was very seriously injured.

The writers believe that available nitrogen applied in the fall has a bearing on this injury. It is evident that under the conditions pre-

vailing in the experimental orchard in the fall and winter of 1937-38, any ordinary amount of fertilizer could have been applied with perfect safety. However, in May 1938, Doctors J. H. Waring and M. T. Hilborn showed the writers a large number of trees in the so-called "stock and scion" orchard of the Maine Agricultural Experiment Station at Highmoor farm near Lewiston, Maine, which had suffered the same type of injury. Cyanamid had been applied to these trees in October 1937, in what might be termed "normal" amounts. While it is not yet possible to define the conditions under which this injury is likely to occur, the writers believe that it may occur when no fertilizer is applied in autumn, though according to observations in New England this happens very, very rarely. Under other conditions, when it would not occur naturally, small or "normal" amounts of fertilizer may induce it; under still other conditions only excessive amounts of fertilizer will cause it.

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## Phosphate Phosphorus and Soluble Nitrogen Changes in Living and Winter Killed Peach Twigs<sup>1</sup>

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THE winter of 1935-36 was unusually cold at Lexington, Kentucky, and lower temperatures were recorded than had been experienced since the memorable winter of 1917-18. On January 22, 1936, a temperature of 18 degrees below zero was registered and on January 27, the temperature dropped to 22 below zero. Very little warm weather had preceded these decided drops in temperature and peach trees were completely dormant at the time the severe cold occurred. As the season progressed, it became increasingly evident that many peach trees had suffered severe injury while the damage to apple trees was comparatively small.

The records of fruit trees at Lexington show, that in an average spring, following a winter during which no injury has resulted to peach buds and wood, the opening of the vegetative buds usually starts from April 1 to April 10, with the blooms opening slightly in advance of the time when any appreciable leaf growth has been made. In comparison, the opening of leaves on apple trees usually starts from April 1 to 15, with the blooms opening from April 20 to May 5.

The spring of 1936 was comparatively early and the first noticeable breaking of apple buds occurred on March 24. At this time no response in growth was shown by 11-year-old Elberta peach trees, while young peach trees of several different varieties were showing some leaf development. On April 21, Winesap apple buds were in the pink condition, while older Elberta peach trees were showing no growth from the previous season's wood and only a few scattering shoots were developing on these trees from adventitious buds on older limbs. Upon careful examination of the older peach trees it was found that with the exception of one tree in the orchard the bark had split vertically on the trunks and had loosened from the trees in most cases. This condition extended outward upon the main limbs at varying distances from the trunk. Several varieties of young peach trees which included Elberta, did not show this type of injury although on most of the branches and trunk areas, black hearted sections of the heart wood were found. Stimmetz (4) found with apple wood that black hearted areas were composed of dead parenchyma cells together with other occluded vessels.

By May 5, a large percentage of the comparatively small number of shoots which had started to grow on the old Elberta trees, had withered and died and the trees were then removed from the orchard. It was evident that all fruit buds and most of the vegetative buds had been killed and that injury to the sap-wood and phloem had been severe. It was of interest in this connection, however, that even at the

<sup>1</sup>The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

time the trees were removed there was but little shriveling of the bark on even the smaller twigs.

Without exception, the young peach trees made a satisfactory recovery during the summer of 1936 and have now developed into excellent trees that have borne two consecutive crops of fruit.

Through the summer of 1935 and the winter of 1935-36, chemical determinations were made at weekly intervals on twigs from the old Elberta group to determine the seasonal course of soluble nitrogen and phosphate phosphorus in the tissues of this variety. The methods have already been described (5). These determinations were continued after the occurrence of the extremely low temperatures previously mentioned and the data in this paper were taken from the record of determinations extending from January 8 to April 28, inclusive.

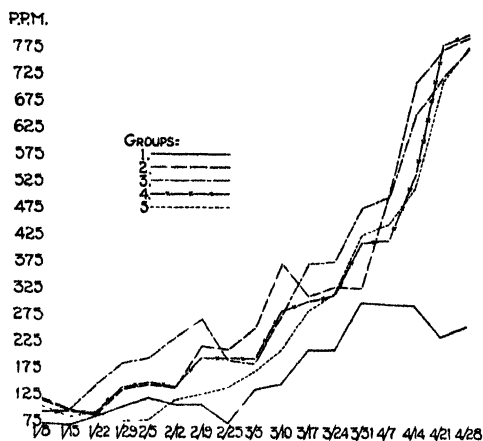


FIG. 1. Seasonal changes in phosphate phosphorus in peach twigs.

The data for phosphate phosphorus are recorded in Fig. 1.

The data from 1935 are used in the table to make possible the comparison of amounts of phosphate phosphorus and soluble nitrogen in the same trees following a more nearly average winter season when no injury had occurred, with the 1936 winter when severe damage had resulted.

In previous work, rather definite relationships were found to exist between the soluble nitrogen and phosphate phosphorus in twig tissues of apple and peach trees. Since the utilization of phosphorus in anabolic processes is dependent upon the soluble nitrogen supply, increase in soluble nitrogen results in lowering the amount of phosphate phosphorus. For this reason, the findings for the soluble nitrogen are presented in this paper.

The trees are grouped in accordance with a nitrogen fertilizer program which was followed during the spring and summer of 1935 (5). The figures for groups 2, 3, 4, and 5 are averages from weekly analyses of four different trees in each group while those for group 1 are averages from the weekly analysis of one tree. This tree was the only one in the orchard which survived the unusually cold winter.

A great many experiments with numerous kinds of plants have been made in an effort to determine the parts played by phloem and xylem tissues in the transfer of mineral nutrients and elaborated food materials. Reports from these experiments have varied in regard to the functions of these tissues. Curtis (2, 3), has found that nitrogen probably moves up as well as down through the phloem and the work of

TABLE I—PHOSPHATE PHOSPHORUS AND SOLUBLE NITROGEN CONTENT OF ELBERTA PEACH TWIGS IN THE SPRING OF 1935 AND OF 1936 (PARTS PER MILLION OF FRESH TISSUE) GROUPS 2, 3, 4, AND 5, WINTER KILLED. NO. 1 INJURED BUT NOT KILLED

	Group 1		Group 2 (4 Trees)	Group 3 (4 Trees)	Group 4 (4 Trees)	Group 5 (4 Trees)
	Live (1 Tree)	(3 Trees)				
<i>Phosphate Phosphorus</i>						
1936 Average January 8 to April 28	175	322	334	347	311	284
1936 Average March 17 to April 28	267	527	545	561	518	505
Per cent increase	52	64	63	62	67	78
1935 Average March 22 to May 2	247	228	261	237	219	231
Per cent increase 1936 over 1935	8	131	109	137	137	119
<i>Soluble Nitrogen</i>						
1936 Average January 8 to April 28	498	454	436	478	415	397
1936 Average March 17 to April 28	442	436	438	460	445	379
Per cent increase (+) or decrease (—)	—13	—4	+*	—4	+7	—5
1935 Average March 22 to May 2	266	272	267	274	295	320
Per cent increase 1936 over 1935	66	60	64	68	51	18

\*+ .046 Per cent.

other investigators as reviewed by Chandler (1) indicates that organic nitrogen may move upward through the phloem. Several investigators have found that the movement of nutrient materials from the soil upward through plants takes place through the xylem tissues. There has been no intention in this paper of designating the path of movement of nutrient materials and the results obtained only serve as a suggestion of what has seemed to occur.

The most significant result found in this work was the very great increase in phosphate phosphorus in all trees which eventually died and the very small increase in the percentage of phosphorus in the one which survived. This is also shown in the comparison of similar periods during the 1935 and 1936 seasons. Some injury occurred on the tree which did survive but the amount was very small in comparison with that of the other trees in the orchard. In this connection it is of interest to note that in all trees which were killed, the increase in phosphate phosphorus for comparable periods was more than a hundred per cent greater in 1936 than in 1935 and that the greater part of this increase occurred during the month of April. In uninjured trees an increase in soluble phosphorus occurs slightly in advance of the time that growth starts but the amount in twig tissues is soon lowered when leaves have been formed in sufficient number so that the phosphorus can be utilized. Likewise an increase in soluble nitrogen in tissues is found as the growing season approaches. This also is quite rapidly reduced when vegetative growth becomes rapid (5).

When the trees were removed from this orchard it was found that practically no root injury had occurred. Considering the very great increase in phosphate phosphorus in comparison with the amounts of soluble nitrogen which were found in the twig tissues of these peach trees it appears that the passage of phosphorus through the stems was not appreciably hindered because of the injury to the sap-wood. With the possibility that part of the nitrogen may be transported through the phloem, it appears that the injury to this tissue may have accounted



for the variations in the amounts of soluble nitrogen found in the different groups which were killed and that the absence of new growth was the reason for increases for soluble nitrogen in 1936 over the amounts found during a comparable period for the same trees in 1935.

The conclusion seems justifiable that the killing of buds and much of the conducting tissue resulted in phosphorus accumulation because this material could not be utilized where new vegetative growth could not be formed.

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## Low Temperature Effects on Woody Plants

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WOODY plants in dormant condition are injured by low temperature to some extent in almost every winter, and in addition when frosts or freezes occur either in early fall or in spring subsequent to the appearance of leaves, flowers or shoots. It is most serious, however, in so-called "test-winters". For instance temperatures during the winter of 1928-29 on the continent of Europe were reported by Schaaf (43) and others to have been the lowest experienced in a century. In the winters of 1917-18 and 1933-34 extremely low temperatures occurred in the northeastern United States. Following each exceptionally cold winter numerous papers appear in the literature recording injury to forest trees, shrubs and fruit trees. Usually ornamentals, nut and fruit trees suffer most severely because species and varieties of desirable characteristics tend to be introduced into regions where they are precariously tender even in the average winter. Injury to fruit trees is almost always of greatest economic importance because they are intensively cultivated on a large scale and represent rather large investments. Even indigenous species may suffer. Following the winter of 1933-34 Cope (6) reported the killing of young maple trees, and severe injury to ash in a hardwood second growth in the Adirondack region of New York.

The problem is met with from the olive orchards of Italy to the forests of Russia and from the tung and citrus orchards of the southern United States to the fruit breeding stations of Alaska. Wherever man lives and frosts occur, perennial plants will be grown that at times will suffer injury from cold. Bradford and Cardinell (4) remarked that the history of winter injury to fruit plants in Michigan teaches one outstanding lesson; namely, the "readiness with which bitter experience is forgotten".

Injury depends in considerable measure on the minimum temperature reached and in most instances the damage seems to be done during a single cold night. Thus Chandler (7) showed that in 1917-18 injury to fruit trees in various areas in New York State was related to the temperature of the coldest night, rather than to average temperatures or even average minima for a period of continued cold weather. In artificially freezing roots of 1-year-old apple seedlings the writer (39) was able to demonstrate a significant increase in injury when the tissues were held 17 hours instead of only  $\frac{1}{2}$  hour at 18 degrees F. Hildreth (28), freezing apple twigs at -20 degrees F, found those exposed 12 hours to be damaged more than those held only 3 hours at the minimum. Yet in the main these differences are small compared to the effect of short exposures to slightly lower temperatures. Day and Peace (18), in working with potted seedlings of forest species, found exposure of more than 1 hour to increase the injury very slowly and sometimes by an almost inappreciable amount.

On the other hand, it has been demonstrated frequently in artificial freezing tests that a rapid fall in temperature is much more injurious

than a gradual one. Winkler (61) found that twigs of various forest and cultivated species which were completely killed by a rapid drop from the freezing point to  $-7$  degrees F could withstand  $-20$  degrees F without injury, provided the lower temperature was reached by a very slow drop over a 10-day period. Chandler (9) found buds of cherry, peach and apple to be especially susceptible to injury by a rapid fall in temperature. Carrick (14) and the writer (39) found the same to be true of apple roots. Anthony, Sudds, and Clarke (1) have reported severe damage to all tree fruits under field conditions in Pennsylvania when, on January 22, 1936, the temperature fell during 9 hours from above freezing to points ranging from 0 to  $-15$  degrees F.

Injury incident to cold weather may be due to desiccation of tissues in cold drying winds. Goff (24) attributed the killing of the needles or evergreen species to loss of moisture by evaporation during a rather extended period when continuous cold weather prevented water movement through the twigs. Injury to the raspberry in Nebraska has been prevented by coating the canes with paraffin. Brierley (3) finds that canes of the Latham raspberry are likely to be killed if the moisture is reduced much below 50 per cent.

The nature and extent of the damage resulting from any given exposure to cold will depend upon the species and variety of plant and its internal condition. Macoun (35) enumerates not less than 10 distinct ways in which woody plants may be affected. Several of these forms of injury result from immaturity of the tissues. If there is late growth in the autumn killing back of shoots may occur. This is especially true if the foliage is injured or destroyed. Crane (16) found about one-third of the last year's growth on defoliated shoots of peach to be killed back. Tukey and Brase (54) had a similar experience with apples in the nursery. The extent of the killing was distinctly greater on plants defoliated September 1st than on those defoliated September 13th. "Maturity" certainly involves the cessation of active growth, reduction in moisture content, and probably also the storage of products of photosynthesis.

Injury in the crotches between the trunk and the main branches is often very serious in fruit trees. Irregular areas of bark are killed, often extending up the inner side of the branch. Unless expensive repairs are made, the tree will break under a load of fruit. The writer has observed crotch-injured trees of Northern Spy in central New Hampshire on which all of the lower branches had broken down following crotch injury a few years before. This type of injury can be avoided by topworking the desired variety on trees of very hardy sorts but this involves considerable expense and greatly delays profitable production in the orchard. It does not seem likely that the bark of the crotch contains much if any more moisture than that in other parts of the tree, but cambial activity probably continues late in these areas. In addition Chandler (10) has pointed out that crotch injury is on the *upper side of branches that have an upright position, and on the lower side of branches that droop*. Most of the foliage is on the lower side of upright branches and the upper side of drooping branches; in other words the injury occurs on the side low in leaf area. Since the products

of photosynthesis would not be likely to be cross transferred in moving down the branch, lack of such storage substances seems to have an important bearing on this type of injury. Horsfall (29) has endeavored to increase the amount of storage products in the crotches by girdling the trunk, but with comparatively little success.

Cleavage of living bark from the trunks of fruit and forest trees is sometimes observed and its occurrence suggests that here too, immaturity is a factor. Macoun (35) observed that it is likely to occur at Ottawa, Canada, when there is deep snow and the ground is not frozen. It has been noted on fruit trees in England by Wallace (56) and is about the only form of injury aside from spring frost injury that occurs there. In New England, following the winter of 1933-34, it occurred extensively on McIntosh, one of the hardiest apple varieties. It is noteworthy that in northern New England, where the lowest temperatures occurred, there was very little of it. Bark splitting was exceedingly prevalent in Massachusetts, but in New Hampshire only one orchard and that near the southern border was seriously affected. Over a series of years when winter temperatures were not especially severe this trouble occurred repeatedly following applications of poultry manure to McIntosh apple trees. Following this type of injury new growth almost always occurs on the inner side of the bark. In a few instances the writer has observed growth from *both* surfaces, wood and bark. Grossenbacher (26) has made the same observation on a forest tree. Since with growth, strains are set up that tend to warp the bark still further from the trunk, the general experience is that it is good practice to nail the bark back to the trunks, using large headed tacks or nails and to cover the cracks with grafting wax.

Collar rot, or crown rot, like bark splitting seems to be associated with immaturity of tissues at the base of the trunk. In this type of injury, however, the bark dies, instead of merely separating from the wood. Generally the area affected is close to the soil, whereas in bark splitting it may extend as much as 30 inches from the ground. A question has been raised as to whether this injury which occurs on apple varieties like Grimes in rather low latitudes is actually due to cold or is of a parasitic nature. Grossenbacher (25, 26) and Thomas (51), who have studied this type of injury on fruit and ornamental trees, feel that the primary factors are immaturity and low temperature. Invading fungi are only weakly parasitic if at all. Magness (33) has found as much as 50 per cent of the trees in some Washington orchards affected by this trouble. Here it was definitely correlated with an excess of soil moisture. If the area affected extends entirely around the trunk, yellowish foliage and reddish bark, symptoms typical of girdling, develop during the season following the injury. In this event bridge grafting must be resorted to, but if the dead area is small it will usually heal provided the soil is pulled away and the tree is given good culture.

In New Hampshire, Rawlings and Potter (42) have reported an injury on McIntosh and Delicious apple trees, which is somewhat similar to crown rot, but considerably more extensive, the whole cylinder of bark being killed, sometimes far up into the branches of

the tree. This occurred following the comparatively mild winter of 1935-36 and seemed strikingly correlated with the use of nitrogenous fertilizer in the fall. In most cases the nitrogen had been applied in October and in at least one instance in November, so late that any influence on activity of the cambium seemed impossible. This injury has been under investigation at the University of New Hampshire, and in a current paper by Tingley *et al.* (52), its experimental production, with typical symptoms, including chlorosis of the foliage and rather distinctive discoloration of the bark and wood, is described. The conclusion is reached that under certain climatic conditions, which cannot as yet be defined, and which probably occur rather rarely, nitrogen applied in the fall may predispose apple trees that have borne a heavy crop to this type of injury.

Sunscald, another form of injury to trunks of apple and other trees, is somewhat similar to the injuries just described but is generally believed not to be due to immaturity or cell activity. Strips of bark are killed on the southwest sides of the trees. The conditions giving rise to this trouble occur rather rarely, but when they do occur a large proportion of the trees in an orchard is likely to be affected. Selby (44) described this injury in 1897 and classified apple varieties according to susceptibility. The view was formerly held that the cause is heat from the sun's rays, or freezing after an activity of the cambium has been induced by the heat of the sun. Mix (37) points out that in late winter the bark on the southwest side of a tree may be warmed considerably above the air temperature by the nearly level rays of the sun just before sunset. When the sun drops below the horizon an extremely rapid fall in temperature will occur, which, as we have previously seen, may cause killing of the tissue even though no extremely low temperature is reached. Mix (37) believes that a drop from freezing to perhaps 6 degrees F occurring in a few hours may cause the injury. He was unable, microscopically or by artificial freezing tests, to detect any growth activity or greater susceptibility in the cells on the southwest as compared to the north side of the tree. Nevertheless, in the work of Tingley *et al.* (52) previously mentioned, it was likewise impossible microscopically or by artificial freezing to detect any difference in cambial activity between fertilized and unfertilized trees. Nor did chemical analysis of the tissue reveal the presence of any extra nitrogen. Yet in January the heavily fertilized trees in the orchard showed a slight loosening of the bark and color photographs made February 3rd show injury typical of that previously found in commercial orchards fertilized with nitrogen in the fall. It may be that in sunscald also the activity stimulated is too subtle to be detected with present histological and chemical methods, and that artificial freezing tests of detached parts are not typical of orchard conditions.

Following a test winter, injury is found even on well matured trees. Contrary to expectations the cambium is comparatively resistant when fully matured. This is indicated by the production of new layers of tissue outside those killed or injured, as was observed on peaches by Waite (55) in 1904. Sorauer (45) in 1906 observed that in fully matured twigs of several tree species, the fine spiral elements of the

xylem are first to show browning. The writer has observed microscopically a ring of browning in the xylem, and another in the cortex of frozen apple roots, with uninjured cambium between. Under these conditions killing of the parenchyma cells of the pith may occur or more frequently the sapwood is killed or injured. Injury to the pith is generally of very limited significance. Leaf and blossom buds on small twigs or spurs may be delayed in opening. Damage to sapwood, however, is very serious, especially if the trunk and large limbs are affected. The injury is characterized by brown or black discoloration of the tissue, giving rise to the term "blackheart". In Europe what is evidently a very similar trouble in the peach is known as "redheart". A number of investigations such as those of Steinmetz and Hilborn (47) show that the vessels become plugged with gum, and that many of the wood parenchyma cells are killed.

The growth of the leaves is checked, or they may even wilt after starting. The injured wood is predisposed to fungus attack and becomes very weak, so that in the case of fruit trees, subsequent fruiting is likely to cause extensive breakage. Resistance to this type of injury seems to follow a seasonal cycle, reaching a maximum at about latitude 44 degrees during January or February. Thus at Durham, New Hampshire, a minimum of  $-31$  degrees F on December 29, 1933, caused extensive damage, but  $-35$  degrees F on January 30, 1935 did but little harm. According to Rein (50) the temperatures immediately proceeding the critical exposure are important. He believes that subjection to rather low, but not killing temperatures causes a progressive increase in hardiness up to about 10 days.

In a Baldwin apple orchard at the University of New Hampshire, rows of trees that had been sprayed with flotation sulphur which does not interfere with photosynthesis survived the winter of 1933-34 while those sprayed in late summer with lime sulphur were very badly damaged. Lime sulphur may reduce photosynthetic activity to perhaps two-thirds the normal. Davis (17) reported that where photosynthesis was reduced by shading, injury to shrubs was increased.

There is also a striking relation to crop production of the previous season, which certainly reduces storage of carbohydrates. In 1933-34 trees that did not bear survived with little injury while bearing trees adjacent and similar in all other respects were entirely killed. At least two instances came to the writer's attention, in which one-half of a Baldwin tree had borne and the other half not, with the result that one-half died and the other lived. There were even fine distinctions based on the time of harvest of the crop. A fruit grower near Montreal, Canada, showed the writer a Wealthy apple orchard in which those trees from which the crop had been harvested early were in obviously better condition than those which had been picked late. A similar occurrence was reported in a Baldwin orchard in Rhode Island. On account of the low price of fruit the apples were not harvested in part of the orchard but remained on the trees until they dropped naturally. These trees were very seriously injured as compared with others from which the crop was picked early. Collison and Harlan (11) reporting a similar experience in New York, point out, however, that trees that

bore heavily as an average for the years 1930-32 withstood the winter of 1933-34 better than those with low crop production records.

Injury is also rather closely related to the state of vigor of the tree. In a small Baldwin orchard belonging to the writer some old trees had been very severely cut back when being top grafted in the spring of 1933. A very vigorous growth resulted which no doubt utilized most of the carbohydrates synthesized by the reduced area of foliage. These trees were killed outright. Others which had been cut back to similar extent about two years previously and had in the meantime put on a good deal of young vigorous wood were practically uninjured. The damage to trees that had been only moderately severely pruned during this period was intermediate.

Pruning, during the winter of 1933-34 both before the critical freeze of December 29th and subsequently, was decidedly harmful. Thus, in December before an orchard of Northern Spy apples at Bennington, Vermont, had been finished, the pruning crew was assigned to a different duty. The trees that had not been pruned were the only ones that lived. This was a general experience throughout the northeastern United States in that winter. Burkholder (5) reports a similar experience with Jonathan and Stayman apple trees at Lafayette, Indiana, in 1935.

Recovery from killing of the sapwood depends upon the formation of a new cylinder of uninjured xylem tissue surrounding that in which the vessels are plugged and parenchyma cells killed. Steinmetz and Hilborn (47) have endeavored to set standards for prediction of recovery based on the extent of the plugging of the vessels and the proportion of parenchyma killed. Both culture and weather conditions following the injury have a decided influence on recovery. Chandler (7) reports that the application of four pounds of nitrate of soda per tree materially improved recovery of peaches in which the xylem was nearly all black, and Wohack (58) records better recovery when potassium salts are applied after injury. Many efforts have been made to determine the morphological or physiological basis for difference in hardiness between different species and varieties of fruit trees, all with indifferent success. Stark (46), who investigated the correlation of hardiness to bound water in twigs of different apple varieties was unable to establish any very satisfactory relation and emphasizes the importance of the ability to recover even though many of the cells may be killed. The writer has seen peach trees rapidly return to normal following sapwood injury that would have killed most varieties of apples.

Killing of the buds, particularly flower buds, is another important type of injury. Flower buds of practically all fruit and nut trees are initiated during the season previous to that in which they open and hence are subject to the hazard of cold weather during the winter. As a rule they are much more tender than leaf buds although Paddock (38) has reported an instance in which leaf buds of the peach tree were killed when flower buds on the same twigs survived. Whipple (59) has observed killing of apple flower primordia but this is rather rare. Killing of the flower buds of the peach, on the other hand, is a very

common and serious source of loss. Like the sapwood, buds increase in hardiness as the winter progresses. Cullinan and Weinberger (13) found the critical temperature for killing of flower buds of the Elberta peach at Washington, D. C., to decline gradually from 20 degrees F on November 8, 1932, to 0 degrees F on January 21, 1933.

Crane (16) found that pruning and nitrogen fertilizer made peach buds susceptible to winter killing during 1927-28 at Morgantown, West Virginia, but in December 1929 Cullinan (12) found 18 per cent killing on fertilized plots at Lafayette, Indiana and 50 per cent on unfertilized controls. Knowlton and Dorsey (31) found that nitrogen applications reduced bud killing in three varieties out of four. Chandler (8) showed clearly that pruning and fertilization delay the rest in peach buds so that in late December at Columbia, Missouri, there was much less growth response to warm weather. It is certain that any growth renders buds more susceptible to subsequent cold weather and this may explain those instances in which fertilizers and pruning proved beneficial. The experience of McMunn and Dorsey (34) in which, during a 7-year period, nitrogen failed to influence the percentage of buds killed, would indicate that with peaches it is about as often injurious as it is helpful. With plums in Minnesota, Strausbaugh (48) considered the breaking of the rest period to be of primary importance. Roberts (40, 41) has reported that killing of flower buds of the sour cherry and a large number of Wisconsin shrubs and trees is greatest in buds that have reached an advanced stage of development. Those of the American elm were the only exception, being hardy irrespective of stage of maturity. In the fully matured stem newly differentiated cells are certainly less resistant than the undifferentiated cambium cells from which they arise, and the situation in blossom buds in different stages of development would seem somewhat comparable. Crane (16) found that the hardiest buds are those with the least moisture and nitrogen. Chandler (9) found that peach buds on branches cut November 20th and allowed to hang in the trees were much more resistant to cold in early January than the more turgid buds on the rest of the tree.

Injury to the roots is very common in fruit trees. Root tissue is relatively tender. The writer (39) found that 16 degrees F is usually critical for roots of one year apple seedlings at their most resistant stage, whereas the tops could readily withstand 0 to -20 degrees F. Carrick (14) found that in fall or late winter roots of most fruit species are more tender than in February or early March. Magness (33) found injury at 17 to 23 degrees F. Both Chandler (10) and Magness (33) found that if apple roots are uncovered in early summer they attain hardiness almost equal to that of the trunk and branches. Uncovering in October so that the roots are subjected to gradually lower temperatures during the fall and winter does not produce this effect.

Following serious root injury trees start growth in the spring, but soon wilt and die. This condition does not occur often because soil temperatures under a good snow cover seldom, if ever, reach the killing point. Macoun (36) has reported rootkilling to be a serious



matter at Ottawa, Canada, in only three winters out of sixty. Goff (24) and Craig (15) describe serious damage to orchards and nurseries of the north central states in February, 1899. Gardner, Bradford and Hooker (22) have assembled data on winter soil temperatures and show that in February, 1899, at Lincoln, Nebraska, a temperature of 7 degrees F was recorded 6 inches underground, and 13.5 degrees F at a depth of 12 inches. The tops of large main roots of most fruit trees would be killed at these temperatures, girdling them beyond recovery. Goff believes that there is more or less incipient root injury nearly every winter. Langord (32) has suggested that rootkilling may be a cause of a sour cherry disorder known as "leafcurl".

Fruit trees are usually grafted or budded on seedlings which may be expected to vary considerably in hardiness because of their inherently heterogeneous nature. Some trees such as the apple may strike root from above the graft union, giving rise to scion roots. Such scion roots have been observed to be more hardy under field conditions by Craig (15); and a greater resistance of these to artificial freezing than corresponding seedling roots was demonstrated by both Howard (30) and the writer (39). More recently Stuart (49) has been able with more refined technique to confirm this finding and to differentiate between the hardiness of roots of different varieties. These seem to conform to generally accepted ratings of the relative hardiness of the aerial portions of the varieties. Stuart's (49) results seem to indicate also that different degrees of hardiness may be induced in seedling roots, depending upon the scion variety with which they are worked. This is somewhat in accordance with the belief of Filewicz (21) who holds that the hardiness of a tree may be increased by grafting certain limbs to very hardy varieties. In general practical experience in this country does not seem to bear out Filewicz's results.

Craig (15), Goff (24) and Anderson (2) have all observed that the mazzard stock for cherries is more tender than the mahaleb, although, as Anderson points out, it is much more desirable in other respects for use in northeastern United States. Emerson (20) has investigated the effect of soil moisture on rootkilling and as might be expected finds more serious damage when the soil is dry. The writer's results would indicate that the difference is due to more rapid changes in temperature in a dry than in a moist soil. If the rate of temperature fall and the minimum reached are the same, damage tends to be, if anything, slightly greater when the soil is wet. From a practical point of view Emerson (20) pointed out that cover crops that mat down and prevent rapid freezing of a soil unprotected by snow, are very advantageous. There is considerably less danger of winter injury to roots under a sod mulch than in cultivated ground.

Some other less important types of injury should be mentioned briefly. Splitting of the trunks of trees is very common in extremely cold weather. It is thought by some to be due to the fact that as water is withdrawn from the cells in freezing, there is greater tangential than radial contraction. A more simple, and possibly adequate explanation, is that the heartwood is likely to contain a large amount of water and that the cracks are formed by expansion of this central core on freezing.

In any event, the cracks tend to close just as soon as the weather moderates and no serious damage is done to the tree.

Killing of the blossoms and young fruit is a serious hazard to the fruit industry and appears to be one of the principal problems in the production of tung nuts in the southern United States. The problem is generally more serious in the south than in the north because of the greater likelihood that warm weather will occur during the winter months, causing the blossoms to open prematurely.

The horticulturist and the forester are interested in preventing winter injury, and in knowing whether injured plants will recover or whether they are not worth trying to save. These questions are difficult to answer. By plant breeding, or by introduction from other regions, hardier strains and varieties may be found that are suitable for definite areas. In general, good culture that keeps the plant in medium but not excessive vigor is to be recommended. It is especially important to obtain good foliage and maintain it in a healthful active condition, and to induce proper maturing before cold weather sets in. In the case of plants which bear fruits or nuts, thinning to prevent overbearing is good practice, when feasible from an economic point of view.

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# Low-Temperature Effects on the Physiology of Plant Organs in Relation to Commercial Storage

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## ABSTRACT

This material will be published in full in *Ice and Refrigeration*.

**I**N this paper consideration of the effects of low temperatures on plants is narrowed to a consideration of these effects on fruits and vegetables in commercial storage. A few of these effects are discussed in the following order: (a) on the physical structure; (b) on chemical composition; (c) on susceptibility to decay; and (d) on subsequent life after removal from storage.

In many commercial products chilling usually results in change in the physical structure. Chilling injury is described, and stated to be the result of exposure to critical temperatures that may be several degrees above freezing. Many of these products are natives of tropical zones although apples, pears, and cranberries are also named in the group subject to this injury. The sugar content in a few products, principally potatoes, is increased at the expense of the store of starch at temperatures just above the freezing point. Respiration is definitely slowed up in most cold-stored products.

Many of the products injured by "chilling" are subject to decay, especially where the injury is in the peel or rind. Sweetpotatoes are named as especially subject to decay under these conditions. Following low-temperature injury many products that are ordinarily harvested and shipped green fail to ripen, while most of the tubers or roots cannot be used for propagation.

# Potassium Content of Leaves from Commercial Apple Orchards

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IN experiments (1) with young York Imperial apple trees grown in sand cultures with varying amounts of potassium, it was found that visible deficiency symptoms did not occur in trees receiving 10 parts per million or more of potassium in the nutrient solution. Growth of these trees increased, however, with increased potassium, when all other nutrients were abundantly supplied, until a concentration of over 60 parts per million was reached. The potassium content of the leaves was found to be closely correlated with both the growth of the trees and the amount of potassium supplied in the nutrient solution. In these tests, vigorous growth occurred in trees having above 1 per cent potassium in the leaves, although the maximum growth did not occur until the potassium content of leaves was above 1.7 per cent. Leaves of trees showing definite deficiency symptoms contained less than 0.7 per cent potash. These results suggested the value of analyses of the leaves of fruit trees as an indication of the potassium supply available to the trees. It is of course recognized that the actual quantities found necessary for good growth in the juvenile trees used in the nutrient experiments may be very different from the quantities necessary for bearing orchard trees. However, it seemed desirable to determine the potassium content of leaves of orchard trees in a number of fruit sections to determine the variation which occurs.

## PROCEDURE

Leaf samples were taken from a varying number of orchards in each of several widely separated fruit sections of the United States. A total of 21 orchards in Pennsylvania, Virginia, West Virginia, and Maryland were included from the Potomac Basin district, 8 from the Hood River, Oregon, district, 12 from the Wenatchee, Washington, region, 8 from the Medford, Oregon, district, and 3 from the Missouri Ozarks. Leaf samples were taken in late July from midway on terminal growths of the varieties Jonathan, Rome Beauty, Delicious, York Imperial, and McIntosh, in so far as these varieties were available in the various orchards. Only trees of the several varieties comparable as to age, soil type, fertilizer application, and general culture were selected for sampling within an orchard. Ten leaves from each of four trees of one variety constituted a sample.

Quantitative determinations of potassium were made on all samples. The material was prepared for precipitation according to the method of Sideris (2). The method of precipitation was that of Wilcox (3). Student's method was used in the statistical analysis of the data.

## RESULTS

The results, which are grouped according to districts, and orchards within districts, are given in Table I. The age of trees sampled, soil

series where known, and whether or not nitrogenous and potash fertilizers have been used in recent years are also recorded.

The potassium content of leaves of Delicious averaged significantly higher than that of the other four varieties. York Imperial and Jonathan leaves were significantly lower than Delicious and Rome Beauty. The potassium content of the Rome Beauty leaves was intermediate between Delicious and York Imperial. McIntosh trees did not occur in sufficient number in enough orchards to get a reliable measure of the relationship of this variety to the others. The varietal relationship relative to the potassium content of the leaves, in general, was the same for the different fruit sections. The varieties York Imperial and Jonathan had lower values than Delicious in all but one orchard where samples were taken (No. 2 of the Missouri Ozark district). There is a suggestion, however, that Rome Beauty was consistently higher than Jonathan in the Pacific Northwest districts, but not as constantly so in the Potomac Basin district. Rome Beauty was higher in potassium content of leaves than Jonathan in every orchard sampled in the Medford, Hood River, and Wenatchee districts, while the data show several reversals in orchards of the Potomac Basin district.

Difference in potassium content (of any one variety) between orchards is also clearly evident from the data presented in Table I. This was especially true with orchards in the Potomac Basin district. Thus leaves from Orchards Numbers 1, 14, 19, 21, and 22 were relatively low in potassium, while leaves from Orchards Numbers 4, 6, 7, and 16 were among the highest sampled in this district. Whether or not orchards of the former group would respond to applications of potash has not been determined. It is known that peaches growing immediately adjacent to Orchards Numbers 1, 19, 21, and 22, located in widely separated areas, have shown potassium deficiency symptoms which have been corrected in every case by potash applications. The potassium content of York Imperial leaves in these four orchards was 0.78, 0.74, 0.59, and 0.49 per cent, respectively.

It seems probable that these trees would respond to applications of potash, particularly in view of the results obtained with young York Imperial trees grown in sand cultures (1). Such trees, receiving 4 parts per million of potassium in the nutrient solution, had 0.68 per cent potassium in the leaves and late in the season showed definite deficiency symptoms. Another series receiving 30 parts per million of this element contained 1.69 per cent in the leaves and made double the growth. In four other series in sand cultures, growth and potassium content of leaves increased with increasing concentrations until more than 60 parts per million were supplied.

Orchard trees of York Imperial and Jonathan having under 1.0 per cent potassium in the leaves, and Delicious and Rome Beauty having under 1.5 per cent, would seem most worthy of study from the standpoint of response to potash applications. If such trees do not respond, there would seem to be little chance that orchards running much higher would do so. Analysis of leaves for potassium would seem to be an important preliminary step to the laying out of potash fertilizer experiments in orchards.

TABLE I—POTASSIUM CONTENT OF LEAVES OF FIVE APPLE VARIETIES FROM DIFFERENT FRUIT SECTIONS

Orchard Number	Variety	Age of Trees (Years)	Soil Series	Recent Fertilizer Treatment*		Potassium Content of Leaves (Per Cent Dry Weight)
				Nitrogen	Potassium	
Potamac Basin District						
1	Jonathan	18	-----	+	-	1.22
	Rome Beauty	18	-----	+	-	1.27
	York Imperial	18	-----	+	-	0.78
2	Jonathan	12	-----	+	-	1.46
	Rome Beauty	12	-----	+	-	1.39
	York Imperial	12	-----	+	-	1.47
3	Jonathan	10	-----	+	+	1.74
	Rome Beauty	10	-----	+	+	1.54
	York Imperial	10	-----	+	+	1.35
	Delicious	10	-----	+	+	1.89
4	Jonathan	14	-----	+	+	1.89
	Rome Beauty	14	-----	+	+	1.91
	York Imperial	14	-----	+	+	1.64
5	Rome Beauty	28	Penn silt loam	+	-	1.36
	York Imperial	28	Penn silt loam	+	-	1.36
6	Rome Beauty	8	Penn silt loam	+	-	1.54
	York Imperial	8	Penn silt loam	+	-	1.72
	Delicious	8	Penn silt loam	+	-	2.73
7	Jonathan	20	Berks shale	+	-	1.83
	Rome Beauty	20	Berks shale	+	-	1.64
	York Imperial	20	Berks shale	+	-	1.62
	Delicious	20	Berks shale	+	-	2.15
	McIntosh	20	Berks shale	+	-	2.02
8	Jonathan	20	Berks shale	+	-	1.17
	Rome Beauty	20	Berks shale	+	-	2.09
	York Imperial	20	Berks shale	+	-	1.34
	Delicious	20	Berks shale	+	-	1.99
9	Jonathan	20	DeKalb shale	+	+	1.56
	Rome Beauty	20	DeKalb shale	+	+	1.52
	York Imperial	20	DeKalb shale	+	+	1.06
	Delicious	20	DeKalb shale	+	+	1.55
10	Jonathan	20	DeKalb shale	+	-	1.57
	York Imperial	20	DeKalb shale	+	-	1.49
	Delicious	20	DeKalb shale	+	-	1.76
11	Jonathan	25	Elliber gravelly loam	+	-	1.64
	Rome Beauty	25	Elliber gravelly loam	+	-	1.70
	York Imperial	25	Elliber gravelly loam	+	-	1.69
	Delicious	25	Elliber gravelly loam	+	-	2.23
	McIntosh	25	Elliber gravelly loam	+	-	1.49
12	Jonathan	22	Meigs gravelly loam	+	-	1.63
	York Imperial	22	Meigs gravelly loam	+	-	1.24
	Delicious	22	Meigs gravelly loam	+	-	1.90
	McIntosh	22	Meigs gravelly loam	+	-	1.76
13	York Imperial	15	Frankstown loam	+	-	1.59
	Delicious	15	Frankstown loam	+	-	2.03
14	Jonathan	14	Frankstown loam	+	-	0.60
	York Imperial	14	Frankstown loam	+	-	0.77
	Delicious	14	Frankstown loam	+	-	1.70
15	York Imperial	35	Frankstown loam	+	-	1.36
	Delicious	35	Frankstown loam	+	-	1.90
16	Jonathan	22	Hagerstown silt loam	+	-	1.89
	Rome Beauty	22	Hagerstown silt loam	+	-	1.75
	York Imperial	22	Hagerstown silt loam	+	-	1.82
	Delicious	22	Hagerstown silt loam	+	-	2.23
	McIntosh	22	Hagerstown silt loam	+	-	2.10
17	York Imperial	25	Hagerstown silt loam	+	-	1.27
	Delicious	25	Hagerstown silt loam	+	-	2.41
18	Rome Beauty	25	Hagerstown silt loam	+	-	1.67
	Delicious	25	Hagerstown silt loam	+	-	1.72
	McIntosh	25	Hagerstown silt loam	+	-	1.66
19	Rome Beauty	5	Sassafras gravelly loam	+	-	0.95
	York Imperial	5	Sassafras gravelly loam	+	-	0.74
	Delicious	5	Sassafras gravelly loam	+	-	1.44
	McIntosh	5	Sassafras gravelly loam	+	-	1.47
20	Rome Beauty	5	Sassafras gravelly loam	+	+	1.39
	Delicious	5	Sassafras gravelly loam	+	+	1.63
21	York Imperial	20	Sassafras gravelly loam	+	-	0.59

\*Plus and minus signs indicate whether or not nitrogen and potash have been used in recent years. In orchards where potash fertilizers have been used, applications have been made on the cover crop rather than beneath the trees.



TABLE I—(Continued)

Orchard Number	Variety	Age of Trees (Years)	Soil Series	Recent Fertilizer Treatment*		Potassium Content of Leaves (Per Cent Dry Weight)
				Nitrogen	Potassium	
Potamac Basin District						
22	Delicious	20		+	-	0.70
	Jonathan	20		+	-	1.24
	York Imperial	20		+	-	0.49
	Delicious	20		+	-	1.51
	McIntosh	20		+	-	1.16
Ozark District (Missouri)						
1	Jonathan	17	Newtonia silt loam	+	-	1.60
	York Imperial	17		+	-	1.82
	Delicious	17		+	-	2.20
	McIntosh	17		+	-	2.13
2	Jonathan	20	Clarksville gravel	+	-	1.63
	Rome Beauty	20		+	-	1.59
	York Imperial	20		+	-	1.92
	Delicious	20		+	-	1.35
3	McIntosh	20		+	-	1.85
	Jonathan	12	Memphis-Knox loam	+	-	1.08
	Rome Beauty	12		+	-	1.84
	York Imperial	12		+	-	1.17
	Delicious	12		+	-	1.68
Hood River District (Oregon)						
1	Rome Beauty	17	Hood silt	+	+	1.86
	Delicious	17		+	+	2.17
2	Delicious	10	Underwood loam	+	-	1.94
3	Delicious	15	Parkdale loam	+	-	1.87
4	Jonathan	20	Hood silt	+	-	1.50
	Delicious	20		+	-	2.12
5	Jonathan	22	Rockford clay	+	-	1.56
	Delicious	22		+	-	1.62
6	Jonathan	15	Wind River sandy loam	+	-	1.63
	Delicious	15		+	-	1.97
	McIntosh	15		+	-	1.28
7	Jonathan	30	Wind River sandy loam	+	-	1.40
8	Rome Beauty	30	Parkdale loam	+	-	1.40
Wenatchee District (Washington)						
1	Delicious	26	Wenatchee loam	+	-	1.87
2	Jonathan	36	Wenatchee loam	+	-	1.41
	Rome Beauty	36		+	-	1.71
3	Delicious	12		+	-	1.75
	Jonathan	24	Wenatchee loam	-	-	1.06
	Rome Beauty	22		-	-	1.66
4	Delicious	18		-	-	1.86
	Rome Beauty	20	Wenatchee loam	-	-	1.99
5	Delicious	20		-	-	1.66
	Delicious	22	Wenatchee loam	+	-	2.26
6	Delicious	9	Lick sandy loam	+	-	1.80
	McIntosh	9		+	-	1.60
7	Jonathan	8	Lick sandy loam	+	-	1.29
	Delicious	8		+	-	1.77
8	McIntosh	8		+	-	1.61
	Jonathan	23	Peshastin sandy loam	+	-	1.28
9	Rome Beauty	23		+	-	1.54
	Delicious	23		+	-	1.63
	Jonathan	20	Cashmere laom	+	-	1.47
10	Rome Beauty	32		+	-	1.76
	McIntosh	32		+	-	1.49
11	Delicious	26	Cashmere sandy loam	+	-	1.90
	Rome Beauty	20	Peshastin sandy loam	+	-	2.17
12	Delicious	20		+	-	2.27
	Jonathan	26	Leavenworth sandy loam	+	-	1.55
	Rome Beauty	26		+	-	1.88
12	McIntosh	26		+	-	1.29
	Delicious	26		+	-	1.86

\*Plus and minus signs indicate whether or not nitrogen and potash have been used in recent years. In orchards where potash fertilizers have been used, applications have been made on the cover crop rather than beneath the trees.

TABLE I—(Concluded)

Orchard Number	Variety	Age of Trees (Years)	Soil Series	Recent Fertilizer Treatment*		Potassium Content of Leaves (Per Cent Dry Weight)
				Nitrogen	Potassium	
Medford District (Oregon)						
1	Delicious	20	Meyer adobe clay	+	-	1.56
2	Rome Beauty	25	Siskiyou sandy loam	+	-	2.34
	Delicious	20		+	-	2.00
	McIntosh	20		+	-	1.97
3	Jonathan	30	Salem sandy loam	+	-	1.88
4	Delicious	20	Coleman gravelly loam	+	-	2.43
5	Delicious	20	Sites fine sandy loam	+	-	1.50
6	Jonathan	20	Climax adobe clay	+	-	1.42
	Rome Beauty	20		+	-	1.43
	Delicious	20		+	-	1.44
7	Jonathan	20	Sites fine sandy loam	+	-	1.55
	Delicious	20		+	-	1.99
8	Jonathan	20	Medford gravelly clay	+	-	1.40
	Delicious	20	loam	+	-	1.88

\*Plus and minus signs indicate whether or not nitrogen and potash have been used in recent years. In orchards where potash fertilizers have been used, applications have been made on the cover crop rather than beneath the trees.

In order to measure the seasonal variation in potassium content of the leaves, samples were taken at several intervals after mid-July from individual trees in one orchard. The results indicated a slight decrease in potassium content in late August as compared with mid-July. While not conclusive, the data indicate some migration of potassium prior to senescence.

The wide differences obtained between varieties is an interesting angle of these studies. Whether or not the relatively high values obtained for Delicious indicate an inherent difference in potassium requirement is a matter to be determined.

Leaf analyses of a given variety showed no significant difference in potassium content between districts. Although several orchards low in potash were sampled in the Potomac Basin district, the average of the leaf analyses for this section is as high as in the other districts.

#### ACKNOWLEDGMENTS

A portion of the analyses reported here were made by Hugh A. Taylor. Leaf samples were taken at Wenatchee, Washington, by C. P. Harley; at Hood River, Oregon, by J. R. Kienholz; at Medford, Oregon, by E. S. Degman; in Missouri by M. A. Smith. C. O. Dunbar collected some of the samples in Pennsylvania.

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# The Influence of Sulphur Dust on the Rate of Photosynthesis of an Entire Apple Tree

By A. J. HEINICKE, *Cornell University, Ithaca, N. Y.*

IN evaluating fungicides or insecticides for practical purposes, the fruit grower must know among other things to what extent the materials used influence the activity of the foliage of the tree. Lime sulphur, for example, may seriously inhibit the food manufacturing ability of the foliage under certain conditions, even though it causes little or no apparent burning (1). The following experiment indicates that finely divided sulphur dust, as compared to lime sulphur solution, has relatively little influence on the rate of photosynthesis of the leaves of an entire tree.

## MATERIALS AND METHODS

The 11-year-old trees used in this experiment were the same ones used the year before for experiments with lime sulphur. The entire trees were enclosed in specially constructed glass assimilation chambers equipped so that accurate determinations could be made of the volume of air used, and of the composition of the ingoing and outgoing air with respect to its carbon dioxide content. The details of construction and equipment of the chambers and the methods followed in determining the rate of assimilation were the same as those previously described (2).

Both trees were pruned during the dormant season mainly by removing much of the 1937 shoot growth near the top of the tree and by thinning out wood throughout the center. They received no special treatment and grew normally in the glass assimilation chambers during

TABLE I—PHOTOSYNTHESIS OF BALDWIN APPLE TREE AS AFFECTED BY SULPHUR DUST

1938	Grams Co <sub>2</sub> Assimilated Average per Day per Tree (Net)		Ratio $\frac{B \times 100}{A}$	Mean Temperature (Degrees F)
	Reference Tree (Untreated)	Experimental Tree (Dusted)		
	A	B	C	D
June 4 to 8 . . . . .	650	649	100	77
June 9 to 13 . . . . .	624	609*	98	75
June 14 to 18 . . . . .	757	674*	89	85
June 19 to 23 . . . . .	692	615*	89	85
June 24 to 28 . . . . .	595	561*	94	79

\*Sulphur dust applied June 9.

the preliminary period. Finely divided sulphur dust was applied on June 9 to the Baldwin tree B, while tree A continued to serve as a reference tree without any further treatment. The application of sulphur dust was very heavy and remained on the foliage as a visible deposit throughout the remainder of the season. Some slight burning of the foliage occurred during the few extremely hot days.

## RESULTS

In Table I are given the average grams of carbon dioxide assimilated per day net, i.e. after allowance has been made for the respiration during the day and night. The first 5-day period beginning June 4 served as a standardization period during which the relationships between the rates of apparent photosynthesis of trees A and B were established. The fact that both trees produced about the same amount of food is probably a reflection of the fact that they were pruned to approximately the same size so as to conform to the dimensions (12 x 12 x 16 ft.) of the chamber. There is some variation in the average activity of tree A as well as tree B during successive 5-day periods. This is probably due to fluctuations in average conditions of sunlight and temperature prevailing during these periods.

During the first 5-day period after the sulphur was applied to tree B, there was practically no change in the relationship of the rates of photosynthesis of the two trees. The reduction in relative rates as a result of the treatment did not exceed 11 per cent on the average during the next two periods, and it was only about 6 per cent during the last 5-day period reported.

It will be noted that the least reduction occurred during the 5-day period when the average mean temperature was lowest. An examination of the records of the rates of photosynthesis of individual days indicates that temperature is a very important factor in determining the extent of injury from the sulphur. During the 11 days in which the temperature was below 90 degrees F the average of the normal relationships was 90.1 per cent; on the 9 days when the temperature was above 90 degrees F, the relative rate was only 79.9 per cent. It is of interest to note that the reduction in relative rate of photosynthesis due to dusting was confined largely to the days of high temperatures. The small amount of burning on the leaves that occurred on such days evidently had no marked effect on the efficiency of the foliage as a whole.

In contrast with these results, the same Baldwin tree in 1937 (2) showed only about 50 per cent of normal activity during the first 5-day period after lime sulphur was applied. On very warm days the activity of the tree sprayed with lime sulphur was reduced to 37 per cent of normal. The greatest reduction of any individual day observed with the dust in 1938 occurred during the 9:30 a.m. to 2:30 p.m. period on June 23. With an average temperature of 96 degrees F the activity of the treated tree was still 72 per cent of the normal relationship. A comparison of respiration rates of the two trees during the night indicates that the differences found would account for only a small part of the differences in the apparent photosynthesis during the day.

The results obtained with the photosynthesis studies under experimental conditions corroborate many practical orchard observations. Mills (4) and others have reported that even though sulphur dust may cause some leaf scorch during extremely hot weather, the leaf burning experienced with such material is usually less than found where lime sulphur had been used. Many growers report that the foliage of the dusted trees remains glossy and dark green in appearance

throughout the season and that the fruit is likely to finish better than with the less milder materials. In applying the results obtained, we should not lose sight of the fact that in a bad scab year it is usually more difficult to secure as good control of the fungus with the dust than with the lime sulphur spray.

#### ACKNOWLEDGMENTS

The author is indebted to A. J. Loustalot and to Martin Potter for assistance in carrying on much of the routine involved in this study.

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# The Effect of Dilute Liquid Lime-Sulphur Sprays on the Photosynthesis of Apple Leaves

By H. W. BRODY and N. F. CHILDERS, *Ohio Agricultural Experiment Station, Wooster, Ohio*

IT has been demonstrated that there may be a marked reduction in the photosynthetic activity of apple leaves when sprayed under greenhouse or field conditions with the stronger 1-40 liquid lime-sulphur spray (1, 4). To avoid the injury often associated with the 1-40 concentration of lime-sulphur, there has been a decided trend in recent years toward the use of the more dilute liquid lime-sulphur sprays, in the so-called summer strengths. Under conditions where scab is not a serious problem the weaker lime-sulphur sprays may prove adequate in scab control and at the same time cause less visible injury to the leaves than the stronger concentrations. While there may be less visible injury to the foliage when the weaker liquid lime-sulphur sprays are used, it is possible that these dilutions, as well as the 1-40 dilution, may cause significant reductions in the photosynthetic process.

This study has been conducted in an effort to determine the influence of the weaker liquid lime-sulphur sprays on the rate of assimilation of Stayman apple leaves.

## METHODS

An apparatus and procedure similar to that described by Heinicke and Hoffman (3) and Heinicke (2) were used in these experiments. The determinations were carried out in the greenhouse during the months of April and May, 1938. The trees employed for study were 1 year old, of the variety Stayman, and were growing in 5-gallon glazed stone crocks. The new shoots, on which leaves were tested, were from 20 to 30 inches in length and had not formed their terminal buds. As a whole, the trees bore a more luxuriant crop of foliage

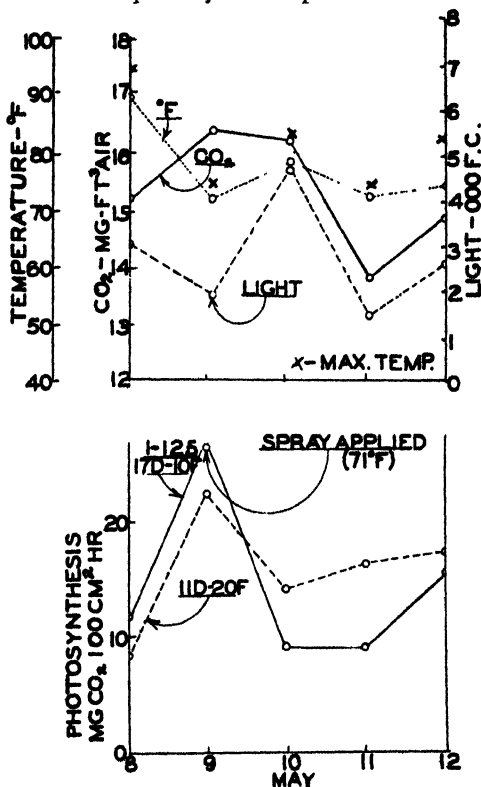


FIG. 1. The effect of liquid lime-sulphur at 1-125 on the rate of photosynthesis of Stayman apple leaves.

than would be expected in the orchard, and, likewise, the rate of photosynthesis for these leaves on clear days was higher than is usually the case under field conditions (3).

In each experiment over a period of 2 to 3 days a relationship in photosynthesis was established among 8 to 10 leaves. Five or six of these leaves then were sprayed with liquid lime-sulphur alone at concentrations of either 1-40, 1-80, 1-100 or 1-125, and the remaining leaves were maintained as unsprayed checks. Spray solutions were applied to the leaves with a hand atomizer in sufficient volume to cause the leaves to drip freely. The determinations were continued for 3 to 5 days after the spray applications. The daily runs started about 8:00 a.m. and lasted from 4 to 5 hours thereafter.

### DISCUSSION OF DATA

The photosynthesis data given in connection with each spray dilution in Figs. 1 to 4 inclusive, are for only one experiment in each case which we considered more or less representative of several. In conjunction

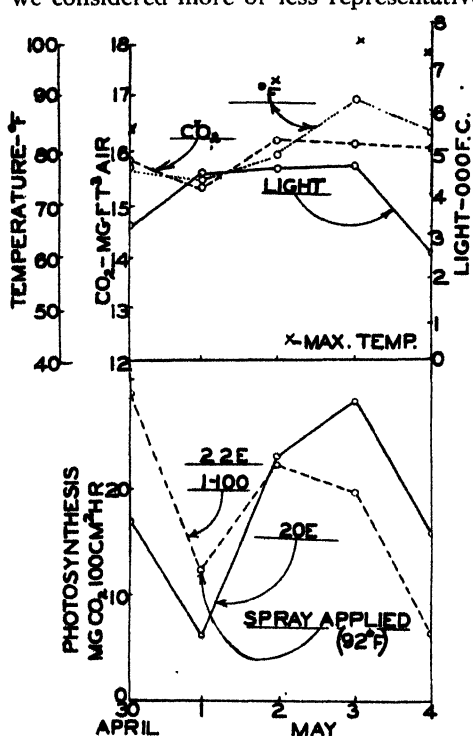


FIG. 2. The effect of liquid-sulphur at 1-100 on the rate of photosynthesis of Stayman apple leaves.

with the photosynthesis data, these figures give, also, corresponding average values for light, temperature, and carbon dioxide. Note that on the left sides of Figs. 3 and 4 the values given for photosynthesis before the sprays were applied represent averages for three previous runs. In each figure the arrow which indicates "spray applied" points to the rate of photosynthesis of the leaf or set of leaves just before spray application. The letter "X" in the upper division of the graphs indicates the maximum temperature recorded during each run. This temperature usually occurred about the end of the run, or at the noon hour. There was no visible burning at any time on the leaves for which data is given here. However in the few cases where burning sometimes

followed by abscission, did occur during the very hot periods. The

rate of photosynthesis of the injured leaves dropped immediately to very low levels with no sign of recovery thereafter. In fact, respiration was often recorded for such leaves.

It is apparent from the data presented in Fig. 1 that liquid lime-sulphur at the relatively weak concentration of 1-125 may cause significant reductions in food manufacture of Stayman apple leaves under this given set of conditions. The spray was applied at a temperature of 71 degrees F. The maximum temperature during any one of the runs did not exceed 83 degrees F; the average temperature was around 75 degrees F. For the days of May 10, 11, and 12, after the spray was applied, the rate of photosynthesis of the treated leaves fell to 50.4, 44.5, and 71.8 per cent respectively, calculated on the basis of their relationship to the check leaves before and after spraying.

Since the critical temperature for lime-sulphur injury is ordinarily considered to be around 90 degrees F, it might be well to cite the results of an experiment where the temperature reached this level after the spray had been applied to leaves at the strength of 1-125 on two separate plants. The temperature at the time of spray application was 68 degrees F and it reached a maximum of 90 degrees during the second and third determinations following. The average temperature for the three runs after treatment was about 80 degrees F. Under these conditions the rate of apparent photosynthesis for the first, second and third days after treatment was reduced to 64.2, 84.0, and 82.1 per cent, respectively, as compared with their pre-spray relationship to the check leaves. While there were significant reductions in photosynthesis in both of the cases cited above, there seemed to be less reduction in assimilation when the temperature reached a maximum of 90 degrees after spray treatment than when it attained a maximum of 83 degrees F. This might be due to differences in humidity conditions. Unfortunately we

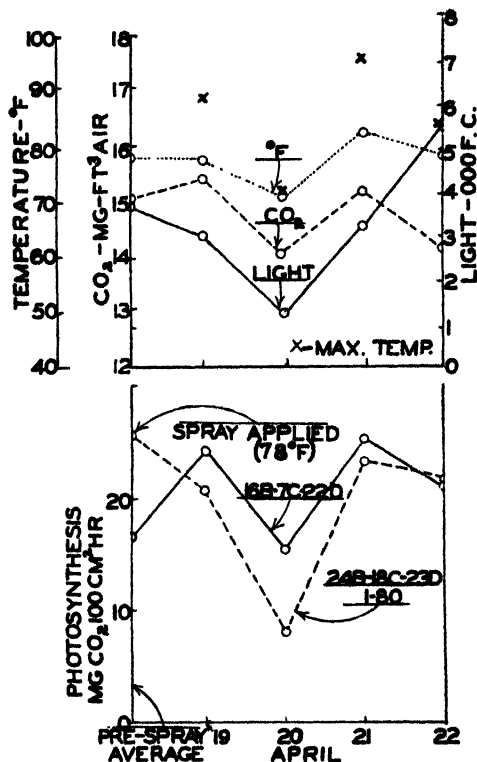


FIG. 3. The effect of liquid lime-sulphur at 1-80 on the rate of photosynthesis of Stayman apple leaves.



have no reliable humidity records available for these experiments.

The data in Fig. 2 show that liquid lime-sulphur applied at the weak dilution of 1-100 may cause a marked reduction in apparent photosynthesis when the temperature exceeds 90 degrees F during each of the four daily runs after spray treatment. The spray was applied at a temperature of 92 degrees F. The rate of assimilation for the sprayed leaf was reduced to 75.5, 40.5, 23.1, and 19.2 per cent respectively, for the 4 days after treatment. This was an average reduction in photosynthesis of about 65 per cent for the 4 days.

In three other separate experiments where 1-100 liquid lime-sulphur was applied to leaves at the somewhat cooler temperatures of 68, 71, and 86 degrees F the average reductions in photosynthesis for the

3 to 5 day periods after each spray treatment were 22.4, 42.1, and 8.2 per cent, respectively. During these tests the maximum temperature reached 90 degrees F on from 1 to 2 of the days after each spray application.

That a reduction in assimilation of apple leaves may result from applications of 1-80 liquid lime-sulphur is shown in Fig. 3. In this particular experiment the spray was applied at a temperature of 78 degrees F. The maximum temperatures for the first, second, third, and fourth days after spray application were 88, 72, 94, and 91 degrees F, respectively. For these 4 days the average rate of photosynthesis of the three sprayed leaves was reduced to 59.8, 35.0, 65.1, and 72.0 per cent, calculated on the basis

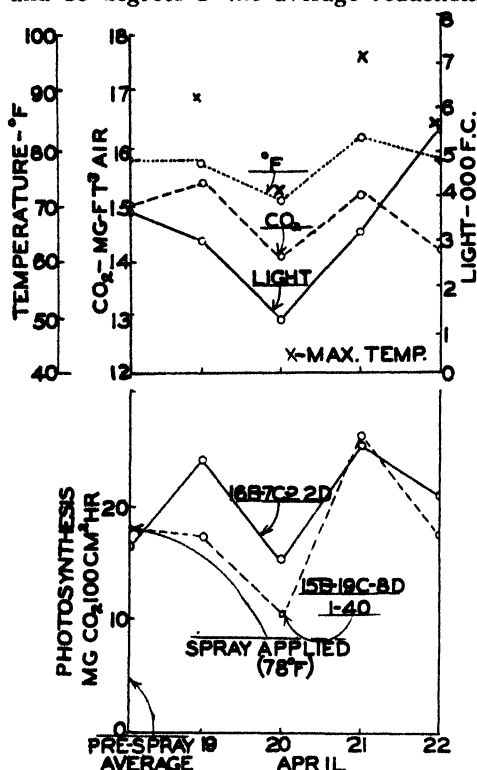


FIG. 4. The effect of liquid lime-sulphur at 1-40 on the rate of photosynthesis of Stayman apple leaves.

of the pre-spray relationship of the leaves to be tested to the check leaves. When 1-80 liquid lime-sulfur was applied to three leaves at a temperature of 86 degrees F, followed by a maximum temperature of 95 degrees on the day after treatment and an average maximum of 83 degrees for the 4 days thereafter, the rate of photosynthesis

in per cent was 80.2, 39.1, 128.8, 30.9, and 104.4, for each of the 5 days.

To complete the range of concentrations of liquid lime-sulphur as they influence photosynthesis, a 1-40 dilution of the spray was tested on a limited set of three leaves. The spray was applied at about 78 degrees F and the maximum temperature exceeded 90 degrees on the first two of the three test days after treatment. On an average, the rate of apparent photosynthesis was reduced to 70.6 and 63.4 on the first two days after spraying, and it then recovered to 100.4 per cent on the third day (Fig. 4). This reduction in assimilation is in agreement with the work of Hoffman (4) and Heinicke (1).

### SUMMARY AND CONCLUSIONS

From this brief report it is apparent that the dilute liquid lime-sulphur sprays may cause marked reductions in the apparent rate of photosynthesis of Stayman apple leaves for 3 to 5 days after spray treatment, even though no visible burning occurs. It is clearly evident that when the maximum temperature reaches 90 to 100 degrees F a significant reduction in assimilation usually occurs regardless of the spray concentration in contact with the leaf tissues. Except for three cases in these experiments, the rate of photosynthesis of sprayed leaves showed a reduction on the first day after treatment. Otherwise the reduction in assimilation occurred not later than the second day following the spray application.

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# The Relation of Leaf Form to Transpiration Rate and Drouth Resistance in Some Deciduous Fruits

By VICTOR W. KELLEY, *University of Illinois, Urbana, Ill.*

IT has long been recognized that in many xerophytic plants the leaves are long in proportion to their width, this being considered an adaptation which reduces the leaf surface, thus lessening the loss of water through the transpiration stream. Coulter, Barnes, and Cowles (4) express their conception as follows: "The most fundamental distinction between xerophytic and mesophytic plants is in the proportion of surface to volume, the former leaves being narrower and thicker than the latter, thus presenting a smaller transpiring surface." In discussing this same question, Schimper (12) states, "The greatest possible expansion of the transpiring surface is the most general characteristic of hygrophytes." Bergen (1) in observations on the sun and shade leaves of 10 species of broad-leaved evergreens, found that sun leaves were usually narrower in proportion to length and thicker than shade leaves.

Insofar as the author has observed, no attempt has been made to correlate leaf form with transpiration rate and drouth resistance with mesophytic deciduous plants. Weiss (14) published length and breadth comparisons for a large number of species but gave no discussion of his measurements. While studying the data of some experimental work (8) involving a comparison of the transpiration rates of 21 deciduous fruit species, the question arose as to whether there might not be a relation between transpiration rate and leaf form, especially the ratio of width to length. It is the purpose of this paper to present the results of the investigation of this relationship.

## EXPERIMENTAL METHOD

*Plant Materials:*—The plants used are fruit species which are growing on the Horticultural Farm at the Illinois Agricultural Experiment Station. They include the economic deciduous tree fruits, several nut species, and a number of small fruits. These species have come to us from several continents and from regions differing greatly in climatic and edaphic features. They vary in size of plant, general form, wood structure, leaf characteristics, extent and depth of root systems, and general ability to withstand unfavorable conditions.

*Measurement of Transpiration:*—The potometer method of measuring transpiration was used. This method was selected because it was considered the most practical for the plants to be studied. With it trees of bearing age may be investigated, several species may be compared, a large number of individuals may be considered, and any number of replications made without exceeding the limits of experimental possibility.

The special type of potometer used in these experiments is illustrated and described in a former publication (8). As was pointed out in that paper, potometers measure the amount of water taken up by the cutting.

In order to compare the amount of water taken up with the amount transpired, several series were run in which the potometer with the plant was weighed to determine the quantity of water transpired, and this was compared to the volumetric reading which is the amount taken up by the shoot. Apple, red raspberry and peach shoots were used in these comparisons, the two former belonging to the high-rate and the latter to the low-rate group. Data for these comparisons are given in Table I.

That so long as apple, peach and red raspberry shoots remain turgid there is little variation in their water content, and that the amount of

TABLE I—THE AMOUNT OF WATER TRANSPIRED COMPARED TO THE QUANTITY TAKEN UP BY CUT SHOOTS

Species	Date	Range of Temperature (Degree F)	Range of Relative humidity (Per Cent)	Shoot Number	Water Taken Up By Shoots (Cc)	Water Transpired (Grams)	Difference (Per Cent)	Condition of Shoots
Apple . . . .	10 a.m. to 5 p.m. March 17	63 to 70	31 to 34	1	6.4	6.6	3.1	Turgid
	5 p.m. March 17 to 8 a.m. March 18	62 to 72	30 to 34	2	4.1	4.1	0.0	Turgid
				1	2.8	2.8	0.0	Turgid
				2	2.4	2.3	4.1	Turgid
Apple . . . .	10 a.m. March 21 to 8 a.m. March 22	50 to 65	40 to 50	3	18.0	18.3	1.6	Turgid
	8 a.m. to 4 p.m. March 22	65 to 77	30 to 38	4	14.7	14.8	0.7	Turgid
				3	6.6	6.4	3.1	Turgid
				4	2.4	2.4	0.0	Turgid
Apple . . . .	10 a.m. to 5 p.m. March 14	62 to 71	22 to 26	5	7.1	7.5	5.6	Visibly wilting
				6	13.6	14.1	3.6	Visibly wilting
Peach . . . .	7 p.m. March 23 to 9 a.m. March 24	66 to 67	30 to 42	7	2.3	2.2	4.3	Turgid
	8 a.m. March 25 to 9 a.m. March 27	70 to 81	32 to 34	8	3.3	3.3	0.0	Turgid
				9	6.2	6.0	3.2	Turgid
				10	4.3	4.5	4.6	Turgid
Red raspberry.	5 p.m. March 28 to 8 a.m. March 29	70 to 80	45 to 49	11	3.1	3.1	0.0	Turgid
	8 a.m. March 31 to 3 p.m. April 1	78 to 82	47 to 53	12	4.0	4.2	5.0	Turgid
				13	6.5	6.5	0.0	Turgid
				14	4.8	4.9	2.0	Turgid

water taken up by the cutting is essentially the same as the quantity transpired as shown in Table I. The differences ranged from nothing to 5 per cent, which is probably no greater than the experimental error. The tests, therefore, with these fruits, are in agreement with the findings of Knight (9), Maximow (11), and Lloyd (10), and indicate that the volumetric method (potometer) gives essentially the same results as the gravimetric method of measuring transpiration with excised shoots.

The shoots selected for the transpiration experiments and leaf measurements were terminal growths of medium vigor from the outside of the plant. All the shoots for any series were from the same plant. The leaf outlines were traced on paper for measurement with the planimeter. Hence, the data presented for leaf form is for the same leaves used to determine the transpiration rate.

## EXPERIMENTAL DATA AND DISCUSSION

With such a large number of species varying in so many characteristics, considerable differences in plant behavior would be expected. This is certainly true of transpiration. Since a detailed presentation of the comparative rates of transpiration was published in a former article (8), only the classification made then will be included in the data presented here.

The relation of leaf form to rapidity of transpiration and drouth resistance is shown in Table II. In the first column the species are

TABLE II—THE RELATION OF LEAF FORM TO TRANSPIRATION RATE AND DROUTH RESISTANCE AMONG FRUIT SPECIES

Ranking According to Transpiration Rate*	Variety	Width-Length Ratio (Per Cent)	Considered Drouth Resistant in Citations Given	Considered not Drouth Resistant in Citations Given
<i>Group 1, High Rate</i>				
Currant . . . . .	Perfection	57.0†	_____	I (918) II (263, 265) V (529)
Filbert . . . . .	Daviana	88.9	_____	VI (124) X (211)
Blackberry . . . . .	Taylor	46.9	_____	I (511) II (107) III (152) V (505)
Quince . . . . .	Champion	75.2	_____	IV (652) V (389)
Black raspberry . . . . .	Quillen	61.7	_____	II (42) III (152) V (517)
Apple . . . . .	Grimes	60.5	_____	I (313)
Pear . . . . .	Kieffer	65.2	_____	I (2506) V (372)
Sour cherry . . . . .	Early Richmond	49.6	IV (246) V (411)	_____
<i>Group 2, Medium Rate</i>				
Apricot . . . . .	Harris	74.0	_____	I (333, 334) XIII (203)
Sweet cherry . . . . .	Gov. Wood	47.8	_____	I (741) III (152) V (411)
Duke Cherry . . . . .	Late Duke	54.0	_____	_____
European plum . . . . .	Imper. Gage	68.0	_____	I (2716) V (457) IX (52)
Japanese plum . . . . .	Burbank	45.0	VI (457)	_____
Gooseberry . . . . .	Poorman	45.0†	_____	I (1358) II (288) IV (295) V (529)
<i>Group 3, Low Rate</i>				
Pecan . . . . .	Warrick	37.0	XI (6-8)	_____
Black Walnut . . . . .	Ten Eyck	36.1	I (3505) X (232)	_____
English Walnut . . . . .	Mayette	37.0	III (150) XIII	I (3501)
Almond . . . . .	Hard Shell	26.8	I (250) III (152) V (398) X (232)	_____
Wild Goose plum . . . . .	Wild Goose	38.9	V (457) IX (52)	_____
Peach . . . . .	Elberta	26.9	I (2495) VIII (6, 142) XII (230)	_____
Nectarine . . . . .	Elruge	29.1	I (2116) VII (118)	_____

\*Classification from Illinois Agricultural Experiment Station Bul. 341.

†Width-length ratio of central lobe.

I. Bailey, Encyclopedia of Horticulture; II. Card, Bush Fruits; III. Chandler, Fruit Growing IV. Downing, Fruits and Fruit Trees of America; V. Fraser, American Fruits; VI. Fuller, Nut Culturist; VII. Hedrick, Encyclopedia of Hardy Fruits; VIII. Hedrick, Peaches of New York; IX. Hedrick, Plums of New York; X. Morris, Nut Growing; XI. Stuckey and Kyle, Pecan Growing. XII. Wickson, California Fruits, 3rd edition; and XIII. Batchelor and Reed, California Agricultural Experiment Station Technical Paper 10.

divided into three groups according to rates of transpiration. Very great differences in rate exist among these groups. Certain species in group 2 transpire about one-half as rapidly per unit area of leaf surface as those in group 1, while those species with the lowest rate from group 3 transpire only from one-fifth to one-third as rapidly as those

having the highest rate in group 1. Considerable differences in rate of water loss also occur among the species within each group. The relation of width to length of foliage is expressed in percentage in column 3, the width being divided by the length. This relationship has been called the "width-length ratio". Resistance to drouth is recorded in columns 4 and 5. This is based upon the opinions of horticultural writers of various periods. These opinions, though not infallible, are the best data available concerning the drouth resistance of the species included in this study. Since horticultural writers seldom mention drouth resistance, the number of references in some cases may seem inadequate. There is a high degree of unanimity among the opinions expressed on drouth resistance there being only one case of disagreement.

The fact that the pecan is indigenous in river valleys has been thought by some critics as sufficient evidence that this species is not drouth-resisting. Such a conclusion, however, is not a valid one. A survey of authorities on pecan culture indicates that two reasons are given for the location of the native pecan in river valleys, neither one of which has anything to do directly with the supply of soil water. There is, on the other hand, direct evidence in the literature of drouth resistance.

The first and perhaps the most important reason for the location of the pecan in valleys is that streams constitute the distributing agency; obviously, streams could distribute drouth resistant plants, as well as those susceptible to drouth. Stuckey and Kyle (13), Colby (3), and Hume (7), all speak of this. A second reason given is the pecan's high fertility requirement. Writers on pecan culture seem to stress soil fertility more than any other feature of its culture. Firor (5), Bixby (2), Hume (7), Fuller (6), Colby (3), and Stuckey and Kyle (13) stress soil fertility. These writers also state that pecans do well on lighter upland soils providing an abundance of fertility is supplied.

Direct evidence that the pecan does not require much water is the fact that a large part of the Texas crop is produced in the western part of the state at an elevation of 800 to 2,500 feet, where the annual rainfall totals only 18 to 30 inches. Stuckey and Kyle (13) describe the climate of this region as "semi-arid" and state that the yield from the 81 counties in this belt was over 13 million pounds. In contrasting the effect of the extremes of altitude and rainfall (20 to 50 inches) upon yield in the Texas region, they report, "As the altitude increases and the rainfall decreases, a larger percentage of the trees produce annual crops of nuts. The nuts are larger and the crop failures are less frequent until the altitude becomes over 2,000 feet and the rainfall less than 20 inches, when the crops become less certain and the nuts smaller. It is evident that, as far as the native trees are concerned, the most regular and the largest yields and the best nuts are secured when the altitude is from 1,000 to 1,800 feet, with the annual rainfall from 20 to 30 inches."

That there is a relationship between leaf form and transpiration rate is indicated by the data in column 3. That group of species which transpires very slowly (group 3) has, without exception, the narrowest leaves in proportion to length. Differences in leaf form between the

species in the high and medium rate groups are not so marked and in a few cases exceptions seem to occur. In the case of the brambles, measurements of the individual leaflets were made; with the current and gooseberry the central lobes were measured. The Taylor blackberry has a very long slender tip (see Fig. 1) which makes it appear, from the measurements, as a somewhat slender leaf. The main body of the leaf has a much higher ratio of width to length. Schimper (12) calls such a tip a "dripping point" and considers it an adaptation of

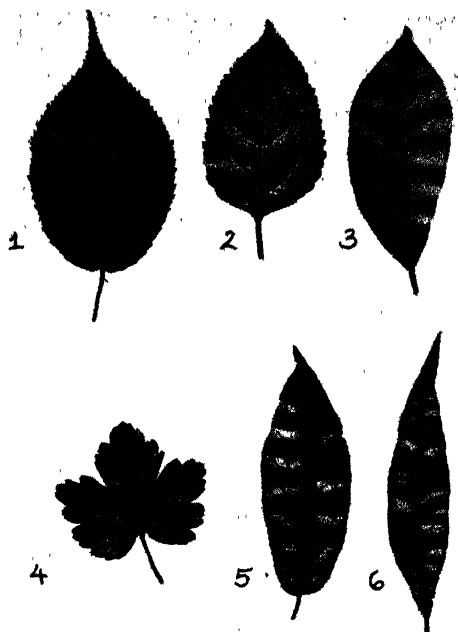


FIG. 1. Showing the shape of leaf in representative species from each group according to transpiration rate: 1, blackberry (Taylor), high rate of transpiration; 2, apple (Delicious), high rate group; 3, plum (Burbank), medium rate group; 4, gooseberry (Poorman), medium rate group; 5, plum (Wild Goose), low rate group; 6, peach (Elberta), low rate group.

plants subject to heavy rainfall, the tip facilitating the draining of water from the leaf. The sour cherry, another species in the high rate group with a somewhat low ratio of width to length, is really on the borderline between the high and medium rate groups and might just as well be classed in one group as the other.

The three species of plums present an interesting study. Imperial Gage has a width-length ratio of 68 while that of Burbank is 45, yet they both occur in the same group on the basis of transpiration rate; Burbank, however, has a considerably lower rate than Imperial Gage. In contrast to these two varieties with a medium rate of transpiration, Wild Goose possesses a very much narrower leaf and has a transpiration rate of less than one-half that of Imperial Gage and Burbank.

### SUMMARY AND CONCLUSIONS

The relation of leaf form to transpiration rate and drouth resistance was studied with 21 species of deciduous fruits. Those species which transpired very slowly had narrow leaves in proportion to length, while those having relatively broad leaves transpired much more rapidly per square inch of leaf surface.

This group of mesophytes exhibits leaf variations and adaptations which, insofar as the author is aware, have been attributed only to xerophytes. Those species which transpired slowly per unit area of leaf surface had relatively narrow leaves and are considered drouth resistant by horticulturists. Narrowness of leaf and low rate per unit area both contribute to drouth resistance. Those species which transpired rapidly had broader leaves in proportion to length and are considered non-resistant to drouth.

It is recognized that drouth resistance may depend upon a number of factors not included in this study, but, unquestionably, transpiration rate per unit area and leaf form as it affects total area are important factors in conserving or exhausting the supply of soil moisture. In this study, narrowness of leaf and low rate of transpiration per unit area are usually combined in the same species.

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# Leaf and Fruit Growth of the Date in Relation to Moisture in a Saline Soil<sup>1 2</sup>

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THE date, grown commercially in the hot, dry districts in the Southwest, is a heavy user of water ; but there has been no work upon the responses of the date palm to insufficient soil moisture. Therefore, in 1938 a study was started to determine the manner in which leaf elongation and fruit growth might be influenced.

## METHODS

Normal growth of leaves and fruit (plot C) in relation to soil moisture was approximated by irrigating every 7 to 14 days. Omission of irrigations in early summer (plot A) and in late summer (plot B) for 6-week periods resulted in the depletion of soil moisture to wilting percentage at two different periods during fruit development. The dates of application of 6 to 10 acre-inches of water (by basin flooding) to each plot are indicated by X, as follows:

	June		July			August		September				
	15	25	7	15	29	10	20	2	10	16	23	30
Plot A	X	0	0	0	X	X	X	X	X	X	X	X
Plot B	X	X	X	X	0	0	0	X	X	X	X	X
Plot C	X	X	X	X	X	X	X	X	X	X	X	X

The rather saline soil, classified as "Indio very fine sand," tended in the upper 2 feet to be a sandy loam, very slowly penetrated by water. The irregularly stratified subsoil was a somewhat coarser sand. The low-vigor Deglet Noor palms had about 10 per cent of their roots in the top foot, 15 per cent in the second, 31 per cent in the third foot, 16 per cent in the fourth, and 13 per cent in the fifth foot.

At any one sampling, individual soil samples from any one plot showed wide variations in texture and moisture content. Also, some soil samples contained more roots than others. Under such conditions the average soil moisture (based on eight samples) may be used only to give a general picture of moisture content of the soil mass in a plot, and does not give an accurate measure of moisture content of soil in contact with (or very close to) the roots. Poor growth of sunflower plants in this soil, together with a tendency for browning of leaves during incipient wilting, prevented determination of the wilting range. Moisture content of soil when lower two leaves remained wilted in

<sup>1</sup>Since date growing under conditions of limited water supply is important to Indians in the Southwest, this study is a part of the cooperative research program between the Office of Indian Affairs, United States Department of Interior, and the Bureau of Plant Industry, United States Department of Agriculture.

<sup>2</sup>C. L. Crawford pollinated the palms, determined root distribution, and helped with fruit measurements.

saturated atmosphere was considered the "permanent wilting percentage". However, reduced rate of moisture extraction by sunflower occurred when moisture content was about 1 per cent higher than the value designated (see Table I) as the "permanent wilting percentage", and permanent wilting of all leaves did not occur until moisture content was from 1 to 2 per cent lower than this value.

TABLE I—PERMANENT WILTING PERCENTAGE FOR EACH OF TOP 3 FEET IN EACH PLOT

Soil Depth (Feet)	Average "Permanent Wilting Percentage"		
	Plot A (Per Cent)	Plot B (Per Cent)	Plot C (Per Cent)
0 to 1	5.1	4.8	4.8
1 to 2	4.4	4.5	4.5
2 to 3	6.9	4.5	4.8

Soil moisture was measured to a depth of 5 feet, but in the 3 to 4 and 4 to 5 feet depths soil moisture was not increased following irrigation and showed only slight differences between plots.

Four of the 10 palms in each plot were selected for study. On each palm one fruit bunch, pollinated on April 2 to 6 (with about 50 per cent of flowers removed 3 weeks after pollinations), was used for fruit measurements; with a comparable bunch for fruit sampling.

The method of measuring leaf elongation was that used by Mason (6), except that the distance of the lower end of the wire above a fixed point on the trunk was measured semi-weekly with a tape. Upper end

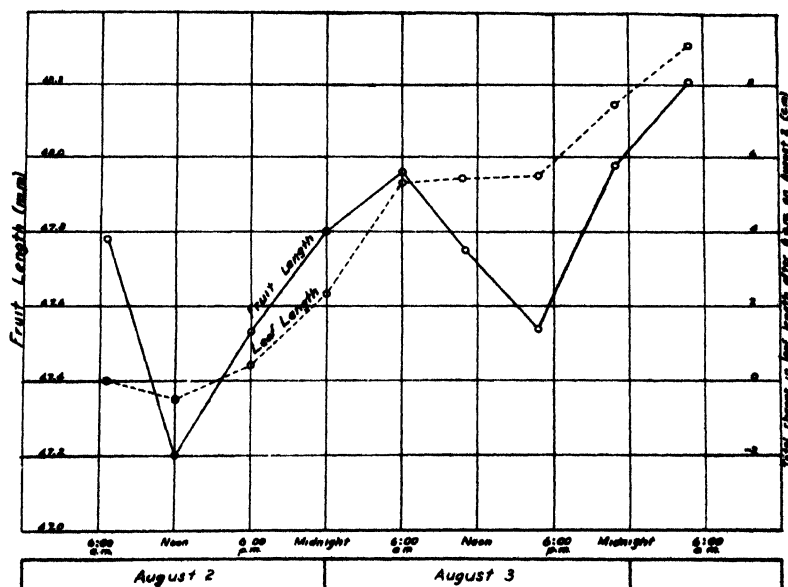


FIG. 1. Diurnal variations in leaf and fruit length.

of wire was attached to leaf just emerging, and was transferred to a new leaf at the end of about 4 weeks. Plot average was based on four leaves on each of four palms. Fruit elongation was also determined semi-weekly, as described by Crawford (4). Elongation of leaves at night but not during the day (see Fig. 1) agrees with Mason's results. Fruit shrinkage during the day emphasized the importance of measuring the fruits as soon as possible after sunrise.

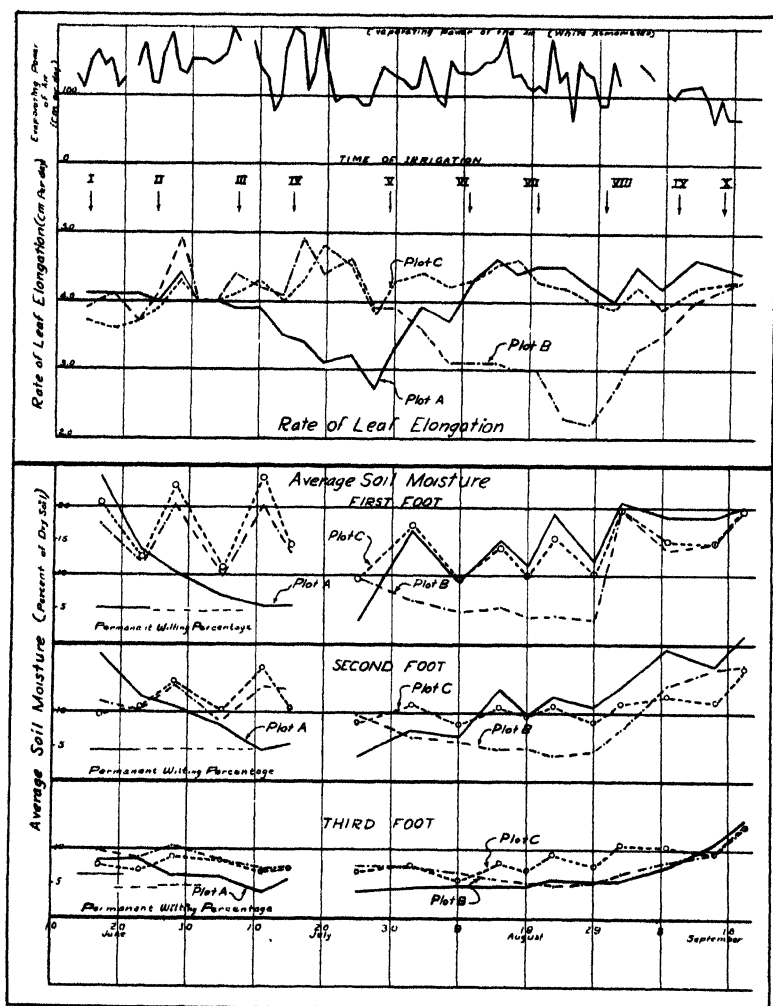


FIG. 2. Average rate of leaf elongation in relation to average soil moisture. Leaf elongation rates are plotted half way between dates of measurement. Soil moisture values are connected with straight lines, with no attempt to indicate moisture content just before or just after irrigation.

## LEAF ELONGATION IN RELATION TO SOIL MOISTURE

Rate of leaf elongation in plot A (see Fig. 2) was initially greater than in plot C. Immediately following the omission of irrigation II in plot A, soil moisture in the third foot was reduced to the permanent wilting percentage, and rate of leaf elongation became about the same as in plot C. By July 7, when many individual soil samples in the first and second feet of plot A showed moisture contents below the average permanent wilting percentage and when the average soil moisture was approaching it, rate of leaf elongation in plot A became less than in plot C. During the July 10 to 29 period, when average soil moisture in each of the upper 3 feet of plot A was at or below the permanent wilting percentage, the rate of leaf elongation was from 9 to 30 per cent less than in plot C. Following irrigation V, when plot A was again irrigated along with plot C, leaf elongation in plot A became equal to that in plot C in about 2 weeks. Even then sufficient water from irrigations V and VI had not penetrated to the third foot to raise soil moisture at that depth above the permanent wilting percentage.

When irrigation V was omitted for plot B, the rate of leaf elongation dropped below that in plot C while average soil moisture in each of the upper 5 feet (data for fourth and fifth feet not presented) was above the permanent wilting percentage. However, on August 2 one out of eight soil samples in each of the upper 3 feet showed a moisture content below the permanent wilting percentage. By August 28, when average soil moisture in the upper 2 feet of plot B had been at or below the permanent wilting percentage for 2 or 3 weeks, rate of leaf elongation was 45 per cent below that in plot C. Following the resumption of irrigation of plot B (with irrigation VIII), average soil moisture in the upper 4 feet (fifth foot not determined) of plot B was increased well above the permanent wilting percentage; but the rate of leaf elongation did not become equal to that in plot C until 3 weeks later.

## FRUIT GROWTH

Curves showing increase in fruit length (not presented) during the summer conform rather closely to those reported by Crawford (4). To obtain a more accurate picture of fruit growth, fresh weight per fruit was determined weekly. At each sampling fruits were selected whose length approximated that of the average length of the measured fruits in that plot on that day. In order to relate fresh weight changes in fruit to stage of fruit development rather than to the calendar, weight per fruit is plotted against number of weeks after pollination (see Fig. 3).

This season fruit of the Deglet Noor variety in this location began to turn from the green to the transitory yellow shades preceding pink during the 19th week. Fruit color was changing from pink to light red during the 21st week, about the time maximum fresh weight per fruit was reached. The first softening of the tip appeared during the 25th week.

In plot A fresh weight per fruit, like rate of leaf elongation, was initially greater than in plot C. During the period between the 13th and 17th week, when reduced rate of leaf elongation followed depletion of

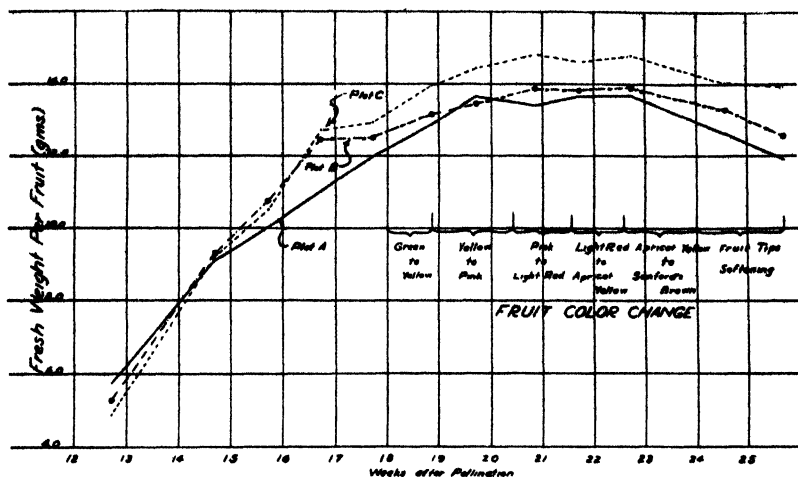


FIG. 3. Changes in fresh weight per fruit in relation to changes in fruit color and to number of weeks after pollination.

soil moisture to the permanent wilting percentage, fresh weight of fruit in plot A increased more slowly than in plot C.

The slower increase in fresh weight per fruit in plot B than in plot C during the period between the 17th and 21st weeks (when greatly reduced rate of leaf elongation followed depletion of soil moisture) was probably the result of this depleted soil moisture. However, inasmuch as the slower increase in fresh weight per fruit in plot B began during the 17th week, when soil moisture averaged as high in plot B as in plot C, it is possible that some other factor than depleted soil moisture was responsible.

Determination of dry weight of fruit without seed is incomplete, but the results thus far (see Table II) show the rapid increase in dry matter in late summer. During the period between the 17th and 26th weeks after pollination, while the rate of increase in fresh weight was slowing down or while fresh weight was decreasing, the rate of dry matter deposition in the fruit was increasing. This is in agreement with the results of Haas and Bliss (5). The data suggest that, while rate

TABLE II—CHANGE IN FRESH WEIGHT PER FRUIT (INCLUDING SEED) AND IN DRY MATTER PER FRUIT (WITHOUT SEED) FOR PERIODS BETWEEN CERTAIN SAMPLINGS

Period Between Sampling	Plot A		Plot B		Plot C	
	Fresh Weight (Grams)	Dry Matter (Grams)	Fresh Weight (Grams)	Dry Matter (Grams)	Fresh Weight (Grams)	Dry Matter (Grams)
June 29 to July 27	5.3	0.8	7.2	0.8	7.9	0.9
July 27 to August 31	2.4	2.9	1.5	2.8	2.1	3.2
August 31 to September 28	-1.5	4.2	-1.3	4.0	-0.9	—

of fresh weight increase was reduced in plots A and B apparently as a result of depleted soil moisture, rate of dry matter increase was not reduced to the same extent.

### DISCUSSION

The cessation of leaf elongation during the day may be due, as Mason (6) suggests, to the inhibitive action of light. Balls (2), studying cotton, and Conway (3), studying sedge, found that leaf growth occurred at night or during daylight on cloudy days, but not during daylight on clear days. Although the direct, inhibitive effect of sunlight may be the principal factor involved, such diurnal variations in leaf growth may also be related to water deficits in the plant. Thus in the case of the date, since the decrease in fruit length during the day was probably due to water deficits in the palm during high transpiration during midday heat, it is possible that lack of leaf elongation during the day was due to a dehydration of cells in leaf base within the trunk. The sensitivity of leaf growth to water deficits in the palm is further indicated by the fact that following 7 of the 10 irrigations of plot C, the rate of leaf elongation showed a temporary increase. Similar observations are reported by Pillsbury (7). This would indicate that just previous to the irrigation the palms were experiencing water deficits in spite of the fact that average soil moisture in each of the upper 5 feet (in plot C) was above the permanent wilting percentage. A somewhat similar stimulation of growth of pear fruits following irrigation of soil with average moisture content already well above the permanent wilting percentage was obtained by Aldrich, Lewis, and Work (1).

The reduced rate of leaf elongation when average soil moisture in one or more of the upper 3 feet (containing about 56 per cent of the roots) was depleted to or below the moisture content at which the two lower leaves of sunflower remained wilted in a saturated atmosphere, together with the increased rate of leaf elongation when such depleted soil moisture was replenished by irrigation, suggests that the rate of leaf elongation may be used as an index of the extent of water deficits in the palm. Whereas reduced rate of leaf elongation was accompanied by reduced rate of increase in fresh weight of fruit (at least in plot A) further study is necessary to determine when water deficits may reduce the rate of dry matter deposition in the fruit.

### CONCLUSION

One year's study of date palm responses to soil moisture indicated: When during the summer average soil moisture in a portion of the root zone was depleted to or below the permanent wilting percentage, the rate of leaf elongation was reduced. Following the replenishment of depleted soil moisture by irrigation, the rate of leaf elongation was usually increased. The apparent sensitivity of leaf growth to amount of soil moisture suggests the rate of leaf growth may be used as an index of water deficits in the palm. Water deficits in the palm, as indicated by reduced rate of leaf elongation, resulted in reduced rate of increase in fresh weight of fruit. While the fresh weight of the fruit was at its

maximum, or was decreasing just before tip softening, the rate of dry matter increase in the flesh was at a maximum.

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# Some Comparisons of Methods of Measuring Fruit Respiration

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## INTRODUCTION AND METHODS

IN evaluating quantitative measurements of natural phenomena the method employed in obtaining such measurements is a factor that is always considered pertinent. In measuring the rate of respiration of fruits and vegetables several methods and their modifications have been used. In this brief study made at the Cold Storage Laboratory at Arlington Farm, Virginia, an attempt was made to make a quantitative comparison of the respiration rates of comparable samples of California lemons as obtained under three systems of measurement. Two of these systems employed a titrimetric determination of the respired  $\text{CO}_2$ , using a KOH solution as the absorbent, and the third a gravimetric determination of the  $\text{CO}_2$ , using "Ascarite" (anhydrous soda-asbestos) as the absorbent. In the gravimetric system, and in one of the titrimetric systems  $\text{CO}_2$ -free air<sup>1</sup> was aspirated over the fruit to remove  $\text{CO}_2$ . In the other titrimetric system the  $\text{CO}_2$  was absorbed by the KOH from a practically static atmosphere. The apparatus used in the latter system was the Magness and Diehl (8) apparatus with Haller and Rose's (5), and Whiteman's<sup>2</sup> modifications. This is the well-known Desiccator-KOH and  $\text{O}_2$ -bottle system, in which  $\text{O}_2$  is supplied to the respiration chamber at atmospheric pressure in automatic response to decreases in pressure within the chamber, caused by absorption of respired  $\text{CO}_2$  by the KOH solution<sup>3</sup> enclosed. For the purpose of convenience this system will be referred to as the "desiccator" system. Identical desiccator respiration chambers, fitted with wire baskets to hold the fruit, were used in all three systems. In the two aspiration systems the funnels piercing the bottoms of the desiccators were used as gas outlets, rather than as containers for KOH solution as in the desiccator system. In the KOH-aspiration system, filter flasks fitted with bead-filled Reiset, Browne and Escombe (1), towers to hold the alkali absorbent<sup>4</sup> were used, and in the Ascarite-aspiration system the  $\text{CO}_2$  was absorbed in Ascarite-filled Nesbitt bulbs (see (5) p. 169). For convenience the former will be referred to as the "tower" system, and the latter as the "Ascarite" system. The  $\text{CO}_2$ -laden air was dried before reaching the Ascarite by bubbling through three concentrated

<sup>1</sup>Air entering the respiration chambers was freed of  $\text{CO}_2$  by bubbling through three gas washing bottles partly filled with 35-40 per cent NaOH, and through one bottle of saturated Ba(OH)<sub>2</sub>.

<sup>2</sup>This modification consisted of replacing beaker "B", Haller and Rose (5), with a 24 centimeter moist chamber cover and replacing the short water tube opening into the  $\text{O}_2$  cylinder with a U-tube extending to near the bottom of the cylinder. The wide shallow vessel reduces fluctuations in the "constant" water level, and the U-tube makes a siphon within the  $\text{O}_2$  cylinder which prevents breakage due to back pressure from the desiccator which may be caused by changes in either atmospheric pressure or temperature.

<sup>3</sup>N/2 slightly diluted by distilled water rinse.

<sup>4</sup>N/5 arbitrarily diluted by distilled water rinse to approximately N/10.



sulfuric acid traps, or by passing through two Nesbitt bulbs filled with "Dehydrite" (anhydrous magnesium perchlorate).

In determining  $\text{CO}_2$  in the titrimetric systems, the methyl-orange phenolphthalein double titration was used in runs 1 to 4 (Table I). Later, as will be noted, a method essentially that of Hopkins (6) was tried, in which carbonate is precipitated out of the KOH by the addition of an excess of saturated  $\text{BaCl}_2$ ; the alcohol and orthocresolphthalein, however, were omitted, and the titration carried out with phenolphthalein, which is the only indicator used. This latter titration procedure was preferred to the double titration since it eliminated the error of an additional end point, avoided the empirical character of the methyl orange end point colors, and gave titration differences (between determination and alkali blank) which, because total carbonate content rather than half of it was determined, were twice the magnitude of those obtained by double titration.

Each system was run in duplicate and the averages compared (see Table I). Flowmeters were used to maintain a constant rate of flow through the four aspiration lines. With the exception of the titrations, the entire experiment, including the weighings, was carried out in a storage room maintained at  $60^\circ\text{F} \pm .5$  degree. To prevent condensation of moisture on the Ascarite bottle, they were weighed on a balance in the  $60^\circ$  degree room.

TABLE I—RATE OF RESPIRATION OF LEMONS (MG.  $\text{CO}_2$  PER KG. HR.)  
AS MEASURED BY THREE SYSTEMS

System:	Ascarite	Desiccator	Tower	System:	Ascarite	Desiccator	Tower
Run 1*—13.4 Liters Hour†				Run 2—13.4 Liters Per Hour			
Sample No.:	1 and 2	5 and 6	3 and 4	Sample No.	3 and 4	1 and 2	5 and 6
April 24-25	7.49†	7.32	7.70	May 1-2	7.52	6.69	7.53
April 25-26	7.25	7.59	8.38	May 2-3	7.38	7.32	8.89
April 26-27	7.24	7.48	8.02	May 3-4	7.48	7.53	8.79
April 27-28	7.42	7.22	7.96	May 4-5	7.69	7.12	7.95
April 28-29	7.16	7.53	7.75	May 5-6	7.51	7.73	8.26
April 29-30	6.81	7.38	8.01	May 6-7	7.24	7.43	7.48
Mean	7.23	7.42	7.97	Mean	7.47	7.30	8.15
Run 3—10.6 Liters Per Hour				Run 4—13.4 Liters Per Hour			
Sample No.:	3 and 4	1 and 2	5 and 6	Sample No.:	3 and 4	1 and 2	5 and 6
May 7-8	6.93	7.79	7.64	May 12-13	7.22	7.53	8.95
May 8-9	7.78	6.96	7.48	May 13-14	6.60	7.22	7.17
May 9-10	6.81	7.74	7.53	May 14-15	6.57	7.19	6.82
May 10-11	7.08	7.64	7.95	May 15-16	6.53	7.83	8.58
May 11-12	6.90	7.84	7.80	May 16-17	6.54	7.49	7.70
				May 17-18	6.60	7.79	7.39
Mean	7.00	7.59	7.68	Mean	6.67	7.51	7.77

\*In runs 1, 2, and 3, three concentrated sulfuric acid traps were used to dry the air entering the Ascarite bulbs. In run 4 two Dehydrite-filled bulbs were substituted for this purpose and the sulfuric acid traps were placed between respiration chambers and absorption towers.

†Rates of aspiration do not apply to "Desiccator".

‡Each figure is an average of simultaneous duplicate determinations. The average percentage coefficients of variability between actual duplicates are as follows, for "Ascarite", "Desiccator", and "Tower", respectively: April 24 to 30,  $\pm 0.5$ ,  $\pm 0.9$ , and  $\pm 1.3$ ; May 1 to 7,  $\pm 0.6$ ,  $\pm 1.4$ , and  $\pm 2.2$ ; May 7 to 12,  $\pm 0.9$ ,  $\pm 1.6$ , and  $\pm 0.1$ ; and May 12 to 18,  $\pm 1.2$ ,  $\pm 0.1$ , and  $\pm 3.4$ .

In the first series of runs (1 to 4, Table I) each sample consisted of comparable lots of eighteen lemons, carefully selected for uniformity by sorting from a full crate of 360 fruits. The fruit, purchased on April 16, was of "Fancy" grade, firm, lustrous, and of a pale yellow color, indicating that it had probably been picked in the light green stage. It proved to be of good keeping quality, maintaining a sound, mould-free condition for about 3 months, or 2 weeks beyond final usage. At the termination of this series of runs the fruit was removed from the desiccators, and after allowance of sufficient time for aeration, several blank determinations on the systems were made. The average of blanks obtained for desiccator and tower systems, which were equivalent to 0.60 and 0.65 centimeter N/10 KOH per 24 hours, respectively, was deducted in making calculations. The results with Ascarite will be discussed later.

A second lot of fruit, purchased in July, was initiated for use as a check series on runs 1 to 4. It proved to be of such poor keeping quality that the results were considered unreliable, and had to be discarded; unfortunately, the study had to be terminated at this point. The series, however, proved to be of value as a trial of the BaCl<sub>2</sub> single indicator method (6) for determining CO<sub>2</sub>, which, for the reasons previously given, was found preferable to double titration.

The blanks obtained on the Ascarite lines, varying from -10 to + 6 milligrams, pointed to some error in the system and suggested the possibility of moisture loss from the Ascarite. In order to check this point, fruit samples of 18 lemons selected as before were placed in the desiccators on the two Ascarite lines, and two Dehydrite-filled bottles introduced into one line at the outlet of the second Ascarite bottle. In the other line a 2-centimeter layer of Dehydrite was included at the top of each of the two Ascarite bottles. By weighing all bottles separately a comparison could then be made of respiratory rates as determined from absorption by (A)<sup>5</sup> Ascarite alone, (B) Ascarite and Dehydrite in separate bottles, and (C) Ascarite and Dehydrite within the same bottles. After seven consecutive 24-hour determinations with this arrangement, the absorption trains were switched from one sample to the other for three 24-hour determinations. In comparing methods (B) and (C) this change constituted a check on possible differences due to sample.

## RESULTS

The results as shown in Table I, analyzed for the significance of differences between desiccator and tower, for means of each run, and for the average of means, gave the values as shown in Table II.

Considering the runs separately, the statistics do not give good indication that the tower values were significantly higher than the desiccator values. If run 3 can be omitted because of the purposely lowered rate of aspiration, which makes it an unfair comparison with the other three runs and the desiccator system which necessarily remained undisturbed, this leaves two out of three runs indicating that the tower values were significantly higher than those of the desiccator.

<sup>5</sup>Correspond to letters in headings of Table III.

TABLE II—STATISTICAL NOTES ON VALUES IN TABLE I

	Difference (Tower - Desiccator)	P*	
Run 1	0.55 milligram, or 7.4 per cent	<.01	Clearly significant
Run 2	.85 milligram, or 11.6 per cent	.016	Clearly significant
Run 3	.09 milligram, or 1.2 per cent	.61	Not significant
Run 4	.26 milligram, or 3.5 per cent	.48	Not significant
Average 1 to 4	0.43 milligram, or 5.8 per cent	.013	Clearly significant

\*R. A. Fisher's "Probability", of occurrence due to chance obtained from "t" test for small samples (4). (.01 corresponds to *reliable* odds of 99:1 and .05 to 19:1) "P" value of .013 obtained from difference between average of means of each run for tower and desiccator.

Even with run 3 included, however, the average of all four, which is perhaps the most important figure, shows an appreciable and a significant difference of tower values over desiccator. The rate of aspiration on run 3 was lowered, believing that it might permit more efficient CO<sub>2</sub> absorption by the Ascarite. Since after this change the mean rate of respiration was lower than before, it at least can not be concluded that absorption efficiency was increased.

The results of the moisture loss tests with Ascarite, given in Table III, show a loss of appreciable quantities of water as CO<sub>2</sub> was absorbed. The switch in fruit samples on July 1 made it possible to calculate respiration rates for (B) and (C) with the sample factor eliminated, that is, the "10-day" averages. Since these two averages were identical, it can be assumed that the differences between the (B) and (C) means were due to sample, and that a desiccant can be used either within the Ascarite-containing bottles, or in separate bottles. On the 10-day average the water loss was equivalent to 2.8 per cent of the respiratory rate as calculated from (A). This apparent requirement of a desiccant is

TABLE III—RESPIRATION OF LEMONS AS MEASURED FROM ABSORPTION BY  
(A) ASCARITE, (B) ASCARITE AND DEHYDRITE IN SEPARATE BOTTLES,  
AND (C) ASCARITE TOPPED WITH A LAYER OF DEHYDRITE IN  
EACH BOTTLE

Date	Mg CO <sub>2</sub> Per Kg. Hr. as Measured by			
	(A) Ascarite	(B) (Ascarite) + (Dehydrate)	Error Due to Water Loss (B) - (A)	(C) (Ascarite + Dehydrate)
	Fruit Sample a			Fruit Sample b
June 24 to 25	13.55	13.85	+ .30	14.50
June 25 to 26	10.81	11.07	.26	11.27
June 26 to 27	9.27	9.56	.29	9.58
June 27 to 28	8.94	9.16	.22	9.16
June 28 to 29	8.24	8.47	.23	8.86
June 29 to 30	8.34	8.58	.24	8.94
June 30-July 1	8.46	8.78	.32	9.30
Mean	9.66	9.92	+ .27	10.23
	Fruit Sample b			Fruit Sample a
	(A) Ascarite	(B) (Ascarite) + (Dehydrate)	Error Due to Water Loss (B) - (A)	(C) (Ascarite + Dehydrate)
	Fruit Sample a			Fruit Sample b
July 1 to 2	8.69	8.93	+ .24	8.32
July 2 to 3	8.91	9.16	.25	8.30
July 3 to 5	9.00	9.31	.31	8.64
Mean	8.87	9.13	+ .27	8.42
10-Day Average	9.42	9.69	+ .266, or 2.8 per cent	9.69

in agreement with the findings of Lundell, Hoffman, and Bright (7), who state (p. 22) in discussing solid absorbents for CO<sub>2</sub> that they "give up water and must be followed by a desiccant when used in weighed systems". They also state (p. 23) that this is contrary to the claims of Stetser and Norton (9) who made the original preparation of the modified soda-asbestos now sold as "Ascarite". Eaves (2), working with "soda-flake" as an absorbent for CO<sub>2</sub>, also found that it was necessary to include a desiccant (CaCl<sub>2</sub>) within the absorption tubes. Although the 2.8 per cent average water loss found here is derived from figures with but little daily variation, it probably cannot be relied upon for use as a general correction factor, since variables such as temperature, rate of aspiration, rate of CO<sub>2</sub> absorption, or the moisture content, fineness, and quantity of Ascarite used, might influence it considerably. If 2.8 per cent is added, however, to the Ascarite means in Table I, it is interesting to note that this brings their average to within 8 per cent of the tower average, a figure which is very close to that shown by Eaves' (3) results from comparing Ascarite plus a desiccant, with Pettenkofer tube and baryta water absorption. This rather large discrepancy is perhaps difficult to explain in view of the fact that Ascarite is a standard CO<sub>2</sub> absorbent for use in determining carbon content of steel (7). In the steel aspiration trains, however, Ascarite is also the agent used to free the incoming air of CO<sub>2</sub>, and although the writer did not have the opportunity to check the point, it is possible that some of the discrepancy was due to the use of the NaOH and Ba(OH)<sub>2</sub> traps at the entrance to the Ascarite lines.

As a check on possible differences in desiccation between aspirated and non-aspirated fruit, samples 1 to 6 were weighed before and after use. The data, given in Table IV, show that the losses were very small in percentage, and that there were apparently no significant differences. This was expected from the early appearance of moisture of condensation on portions of the under surface of all of the desiccator covers, which was indicative of high humidity.

TABLE IV—EFFECT OF MOVING AND STILL AIR EMPLOYED IN RESPIRATION SYSTEMS ON LOSS OF FRESH WEIGHT OF LEMONS

Fruit Sample	Weight (Grams) April 23	Number of Days		Weight (Grams) May 18	Loss of Weight in	
		Aerated*	In Still Air†		Grams	Per Cent of Original
1	1784	6	18	1774	10	0.47
2	1808			1801	7	
3	1789			1782	7	
4	1772	24	0	1768	4	0.31
5	1779			1773	6	
6	1762	18	6	1757	5	0.31

\*In aspiration systems.

†In desiccator system.

## DISCUSSION

In considering a choice of methods, from the viewpoint of the writer the use of the desiccator system has two chief disadvantages: (a) that of the desiccator itself being too limiting on sample size, especially where large or highly variable fruits are being tested, and (b) that, as

Haller and Rose (5) state, "it is desirable that the size of the sample be so regulated that about 200 to 300 centimeters of  $O_2$  are used and about a third of the KOH neutralized by the  $CO_2$  evolved during a run". A tower or Ascarite system, in contrast, can be easily set up so as to allow considerably greater latitude in  $CO_2$  absorption capacity, and therefore not require any definite regulation of sample size, which in the case of unfamiliar material can only be guessed at. Although the desiccator system has the advantage of being the only one of the three systems studied which gives  $O_2$  consumption data, whether this compensates for the disadvantages or not, is a subject that in most fruit respiration studies is at least open to question.

Irrespective of the significance of any differences reported here, or of the relative merits of one system over another, it becomes increasingly evident on delving into the subject of respiration measurement that few, if any, of our present methods give us an *absolute* and unaffected measure of plant respiration. In most aspiration systems, for example, it can be argued that rates obtained might be too high because of the negative pressure which usually exists. In the aspiration systems used in this experiment this actually amounted to 36 millimeters of mercury, while the desiccator system used in comparison necessarily remained at atmospheric pressure. On the other hand, in the desiccator system for example, it can be argued that rates obtained might be too high, due to the ripening effect of accumulating "volatiles", or too low, because of sub-normal  $O_2$  percentages in the desiccators, which might result from an  $O_2$  supply from the cylinders which had been diluted by back-and-forth movement of gases caused by changes in atmospheric pressure. Yet, it must not be overlooked that in many experiments absolute values are not essential, and since data are usually secured by a single method of measurement, they may therefore at least serve the purpose of comparability within the experiment.

### CONCLUSIONS

In a brief study of fruit respiration a comparison of rates was made as measured by two titrimetric systems, one employing Reiset towers and the other a modified Magness and Diehl apparatus. The results indicate that the latter system gives values approximately 6 per cent lower than the former.

Values obtained from a gravimetric system run simultaneously with the other two, and employing Ascarite as the  $CO_2$  absorbent, emphasized the necessity for use of a desiccant to absorb the water given off by Ascarite in its absorption reaction. The fact that the Ascarite values were approximately 8 per cent lower than those obtained with the tower system, even after allowing for a desiccant error, also suggests that precautions in addition to that of the use of a desiccant might well be considered in precision studies.

It has been assumed, solely on the basis of magnitude, that the tower system gave the most nearly correct rates.

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## The Effect of Copper Compounds Applied to Spur Units During Bloom upon the Set of Apple Fruits

By L. H. MACDANIELS and E. M. HILDEBRAND, *Cornell University, Ithaca, N. Y.*

PREVIOUS investigations (1) have indicated that the application of copper compounds and other bactericides to apple blossoms has not materially reduced the set of fruit when branch units and whole trees were used. In as much as these compounds were shown to be toxic to germinating pollen on agar media, it was believed that their failure to inhibit fruit set when sprayed or dusted on the blossoms was due to a lack of contact between the pollen grains and the toxic materials. This would be true if the bactericides reached the stigmas so long after pollination that the pollen tube had penetrated the style and was thus not injured or if blossoms opened subsequently to the application of dusts or sprays and therefore the stigmas were free from the toxic materials. It was also pointed out that the papillae of the stigma were of such a nature that they were not easily wet by spray and that there was a possibility that between the papillae there probably were spaces unoccupied by dust or spray where pollen grains could lodge and germinate.

The investigation herewith reported was planned to obtain information regarding the specific effect of 20-80 copper-lime dust and 2-6-100 Bordeaux mixture applied to the stigmas of apple blossoms on spur-units on the set of fruit. These materials have proved to be the most practical for the control of fire blight in commercial orchards when dusted or sprayed on the blossoming trees (2).

In the experiment, 50 or more of the most vigorous and uniform spurs on each of 12 heavily blossoming 25-year-old Northern Spy apple trees were covered with 2-pound glassine bags. The trees were somewhat under-vigorous and rather bushy. Their use was necessitated by injury to the blossoms of earlier blooming varieties by a late frost. Only two of the more vigorous flowers were left on each blossom cluster. In one series using six trees both of these flowers received identical treatments in both pollination and application of spray and dust. In the other series of six trees both flowers on the same spur received the same treatment with pollen, but only one was sprayed or dusted. On each of the 12 trees the flowers on 10 spurs were pollinated and treated with spray or dust the same day, 10 pollinated the first day and treated 24 hours later, 10 treated the first day and pollinated 24 hours later, and 10 spurs each were pollinated on the first and the second day but were not sprayed or dusted.

Delicious pollen was applied to the stigmas with a camel's hair brush as was the copper-lime dust. Bordeaux mixture was sprayed upon the stigmas with an atomizer. Applications to the stigmas were heavier than would be probable in routine commercial spraying.

The set of fruit upon the trees as a whole was very heavy, which, coupled with a rainfall deficit and a none too vigorous condition of the

TABLE I—EFFECT OF COPPER COMPOUNDS APPLIED DURING BLOOM ON SET OF APPLE FRUITS (TWO FLOWERS PER SPUR TREATED ALIKE, SPRING, 1938)

Date Pollinated	Date Treated	Number Flowers	Number Fruits May 25	Number Fruits July 13	Number Fruits per 100 Flowers July	Per Cent of Comparable Check
<i>20-80 Copper-lime, Dust Trees 1, 3, and 5</i>						
May 5	—	66*	56*	49*	74	—
May 6	—	66	45	35	53	—
May 5	May 5	66	47	32	48	65
May 5	May 6	76	41	31	41	55
May 6	May 5	74	23	13	18	34
<i>Bordeaux Mixture 2-6-100, Trees 2, 4, and 6</i>						
May 5	—	74	56	41	55	—
May 6	—	76	64	49	65	—
May 5	May 5	66	54	43	65	118
May 5	May 6	70	48	36	51	93
May 6	May 5	68	50	30	44	68

\*Each figure is the sum of three sets of 10 to 12 spurs receiving identical treatment on three different trees.

trees probably related to winter injury, resulted in fruit of small size. These generally unfavorable growth conditions may have reduced the set on the bagged spurs so that even the checks did not set as well as might be expected. Table I gives the data from the six trees on which the two flowers on the same spur received the same treatment. In the right hand column the set from each treatment is given as a percentage of the comparable checks that were pollinated the same day. It is to be noted that the lowest set with both materials is on the spurs which were sprayed or dusted 24 hours before pollination. Also the set has been reduced on five out of the six treatments. It is rather surprising that the flowers treated with copper set at all. In this series the dust has reduced the set more than the spray. However, the reverse is true with the other series as shown in Table II.

TABLE II—EFFECT OF COPPER COMPOUNDS APPLIED TO APPLE FLOWERS ON THE SET OF FRUIT (TWO FLOWERS POLLINATED PER SPUR, ONLY ONE TREATED WITH COPPER, SPRING 1938)

Date Pollinated	Date Treated	Number Flowers	Fruits May 25th		Fruits July 13th		Sum July	Number Fruits per 100 Flowers	Per Cent of Comparable Checks†
			Treated	Un-treated	Treated	Un-treated			
20-80 Copper-lime Dust, Trees 7, 9, and 11									
May 5	—	82	—	31*	—	22*	22	27	—
May 6	—	70	—	27*	—	15*	15	21	—
May 5	May 5	66	9	13	8	10	18	27	100
May 5	May 6	64	16	20	12	17	29	45	167
May 6	May 5	60	9	12	9	9	18	30	143
Bordeaux mixture 2-6-100, Trees 8, 10, and 12									
May 5	—	72	—	35*	—	27*	27	37	—
May 6	—	68	—	36*	—	22*	22	32	—
May 5	May 5	64	12	20	9	17	26	41	111
May 5	May 6	74	25	22	16	13	29	39	105
May 6	May 5	60	11	18	10	15	25	42	131

\*Both flowers on spur were pollinated but received no other treatment.

†The data are given in this way to emphasize the fact that the spurs without flowers treated set more fruits in the aggregate than the comparable checks even though the treated flowers set less than the untreated flowers on the same spurs.



Table II gives the results for six trees on which the two flowers on each spur were treated alike in pollination, but on the spurs receiving bactericides, only one flower was sprayed or dusted. An outstanding feature of these data is that in all cases the set on the treated spurs is either equal to or greater than that of the corresponding checks. In other words, the spurs on which one flower was pollinated only and the other both pollinated and sprayed or dusted set more fruits in the aggregate than the spurs on which both flowers were pollinated but received no spray or dust. The only suggested explanation of this result in the light of the data of Table I and of other pollination investigations is that the lighter set was caused by competition for food and water between flowers on the same spur. Where both had an equal chance to set, competition was such that more flowers were abscised than on the spurs where one flower may have been at a disadvantage because of treatment with spray or dust. That abscission of all flowers on a spur may follow equal competition of several flowers on the spur has been frequently observed.

In the series in which treated flowers were compared with untreated flowers on the same spur, the set of the treated blossoms was less than the untreated in 11 instances, greater than the treated in six and equal in two. This indicates that the treated flower was at a disadvantage but is not particularly convincing. On these same spurs the number of treated flowers setting fruit was less than the comparable check in eight instances and greater in 10. The number of untreated blossoms setting fruit was less than the comparable check in five instances and greater in thirteen. This is a further indication that the inhibiting effect of the treatment upon one of the flowers increased the percentage of spurs holding one fruit as compared with the spurs on which both flowers supposedly had an equal chance to set.

TABLE III.—EFFECT OF BACTERICIDES APPLIED DURING BLOOM ON AVERAGE NUMBER SEEDS PER FRUIT

Date Pollinated	Date Treated	Number Fruits	Average Number of Seeds per Fruit
May 21		203	4.6
May 21	May 21	210	4.3
May 21	May 22	212	4.6
May 23	May 21	164	5.6

Table III gives the seed count of fruits obtained in the branch unit experiments reported in 1937 (1). The seeds were taken from all the fruits on four sets of 14 unit branches on 14 trees. The treatments applied with pollination, and 24 hours later show no significant differences as compared with the checks. The number of fruits from branches with flowers pollinated 36 hours after treatment is less than that from branches on which the flowers received pollen only but the average number of seeds per fruit is more. It is suggested in this connection that possibly more seeds were required to make the blossoms set on spurs so treated. It hardly seems likely that the copper would have a stimulating effect upon seed production, although it must be admitted that the effect of copper upon plant growth is not well understood and

is in some cases stimulating to plant growth. In this instance the delay in pollination because of rain may have had more effect than the treatment with copper.

### DISCUSSION

In view of the demonstrated toxicity of these copper compounds to pollen germination, their application to the stigmas of apple blossoms has not given the expected results in reducing the set. It is probable that the explanation is related to the location of the pollen grains upon the papillose stigma with relation to the grains of copper lime dust and the failure of the spray to completely cover the stigmatic surface. This is indicated in the work of Hildebrand (2). Probably a microscopic study of the germination of pollen upon the treated stigma would give further information. This investigation certainly emphasizes the very complex nature of the fruit setting process and the many factors involved. From a practical standpoint the data herewith presented give additional weight to the statement that these copper compounds may be applied to blossoming apple trees without seriously reducing the set of fruit.

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# The Removal of Soot, Deposited by Smoke from Industrial Sources, on Apples Grown in the Bottomlands Along the Ohio River in the Northern Panhandle of West Virginia<sup>1</sup>

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**I**N the northern panhandle district of West Virginia are quite a few apple orchards on the bottom lands of the Ohio River. These bottom lands on both sides of the river are also the site of numerous factories and brick-yards, which, together with the rail and river traffic, liberate large amounts of smoke into the air. Because of the damp, heavy, often foggy atmosphere and the confining effect of the river hills, much of the smoke settles down as soot upon everything within the immediate valley region. By harvest time, apples in the riverside orchards are covered with a black, greasy film, which is especially heavy in the stem cavities. The fruit on the trees closest to the river receives the heaviest coating of soot, the intensity of the deposit diminishing back from the river so that fruit a mile away is scarcely soiled. Orchards on the uplands along the river are out of the soot area.

In 1937, the matter of soot removal became an acute problem in this district when fruit purchased by the Federal Surplus Commodities Corporation was thrown out of grade by the inspection service. The problem was brought before the workers at this station. Although the fruit in one of the problem orchards was washed during the season of 1937 in a new Bean Model E underbrush-flood machine using hydrochloric acid, the fruit was graded down because of the remaining soot which was still heavy, especially in the stem ends. Work on the problem was undertaken with apples of the Willow Twig variety from the 1938 crop.

Preliminary trials were conducted in the laboratory. Washing solutions were prepared in a 4-gallon stone jar. A sample of three apples was placed in a wire basket which was then submerged with a rapid downward movement into the solution. After initial submergence the apples were permitted to float for  $\frac{1}{2}$  minute, after which they were submerged again; this procedure was repeated for a total exposure of 2 minutes to the washing solution. The fruit was then thoroughly rinsed under the water tap. A similar technique had been used by the senior author at the University of Illinois when working on spray residue removal under the direction of W. A. Ruth, who had found that the procedure was comparable to a flotation type of washer. It was felt that this method was applicable to the problem of soot removal because, after the inability of the underbrush washer to touch the deposit in the stem ends, it seemed that it would be necessary to loosen the film of soot in the cavity so that it would be washed out in the rinse water.

<sup>1</sup>Published with the approval of the director of the West Virginia Experiment Station as Scientific Paper No. 212.

In the first group of preliminary trials, solutions were used at temperatures of 70 and 110 degrees F. The solutions tried were 1 per cent hydrochloric acid, with and without Vatsol, at concentrations of 0.005 and 0.5 per cent; "BW" brand sodium silicate at 0.25 and 10 per cent; and mineral oil, 1 per cent by volume, emulsified with soap. None of the acid or acid-Vatsol combinations was at all satisfactory under the experimental conditions. The 10 per cent "BW" silicate at 110 degrees F was better than the acid combinations but did not seem promising. The other "BW" solutions were but little better than the acid solutions. The mineral oil-soap emulsion at 110 degrees F was the best combination tried, as it loosened the soot in the stem end and, with a strong rinse, removed it fairly well. The mineral oil seemed promising enough for a trial in the washing machine at the problem orchard.

In the first trials in the Bean Model E underbrush-flood machine, the following combinations were tried: 1 per cent hydrochloric acid, with and without enough Vatsol to cause a foam, at 100 degrees F and 1 per cent (by volume) mineral oil (approximately 150 seconds Saybolt), emulsified with soap at 100 degrees F. Although it was not given a preliminary trial in the laboratory, kerosene emulsified with Nopco 1216-K, a product of the National Oil Products Company, was also tested; 2 quarts of kerosene emulsified with a pint of the material were used to approximately 60 gallons of a washing solution containing 1 per cent hydrochloric acid. None of the combinations was at all satisfactory. The Nopco 1216-K-kerosene emulsion attacked the asphalt paint in the wash tank. The mineral oil emulsion was also fortified with about 10 pounds of "BW" silicate, which amount was all that was available, but no real improvement was noticed. This mineral oil combination removed the soot from the sides of the fruit but did not get it out of the stem cavity.

Further trials were undertaken in the laboratory. After the failure of the mineral oil in the machine, it seemed that something quite drastic would be necessary. The problem was apparently one of removing chemically the natural waxy coat of the apple, since the soot appeared to be held mechanically by this wax deposit. A trial and error method was initiated, using the wire-basket-stone-jar technique. A solution was prepared of one material and a sample washed. The solution was then fortified with another material and another sample was washed, and so on through the various combinations listed below. The temperature became gradually lower for each successive combination as facilities for maintaining the temperature were not available, and it was more desirable to add the new ingredient to the preceding mixture than to make up an entirely new solution for each combination. The solutions tried, all of which were followed by a thorough rinsing under the tap, were:

1. Approximately N/4 sodium hydroxide at 140 degrees F.
2. Same as 1, plus enough soap for a good suds at 135 degrees F.
3. Same as 2, plus enough "BW" silicate to make a 0.25 per cent solution at 120 degrees F.
4. Same as 3, plus enough "BW" silicate to make a 10 per cent solution at 115 degrees F.

5. Same as 4, plus enough mineral oil to make an emulsion, 1 per cent by volume, at 110 degrees F.
6. Same as 2, but sample floated in lukewarm water and soap suds for from 5 to 8 minutes before washing.
7. Same as 3, but with a preliminary soaking as in 6.
8. Same as 4, but with a preliminary soaking as in 6.
9. Same as 5, but with a preliminary soaking as in 6.
10. Same as 5, but with a preliminary soaking in a warm soap-oil emulsion (oil 1 per cent by volume).
11. Soaked 5 minutes in lukewarm 0.25 per cent "BW" silicate solution, then washed in 1 per cent hydrochloric acid plus Vatsol (0.5 per cent) at 110 degrees F.
12. Soaked 5 minutes in lukewarm 10 per cent "BW" silicate solution, then washed as in 11 at 110 degrees F.
13. Soaked 5 minutes in lukewarm 10 per cent "BW" silicate solution plus enough soap for a good suds, then washed as in 11 at 105 degrees F.
14. Soaked 5 minutes in lukewarm 10 per cent "BW" silicate solution, plus soap, plus enough sodium hydroxide for N/8 solution, then washed as in 11 at 100 degrees F.

None of the above combinations proved satisfactory, although the 10 per cent silicate-soap-alkali solutions (trials 4, 5, 8, 9, and 10) did seem to loosen the soot most effectively. The tandem washes, 11, 12, 13, and 14, were definitely ineffective. The trials showed that it was impossible to float the soot from the stem ends. The addition of alkali was an improvement as it removed the wax coating of the apple and aided removal from the sides of the fruit. However, injury in the nature of skin cracking was almost immediately apparent when alkali was used, particularly at the higher temperatures (trials 1, 2, 3, and 4).

A brushing technique was tried. The presoaking solution used in trial 14 was available. An apple, held in one hand, was immersed in the solution and gently brushed by twirling a fiber brush such as is used in laboratories for cleaning beakers. The apple was pressed lightly against the brush, the motion of which caused the apple to turn. The apple was brushed for 30 seconds and then thoroughly rinsed under the tap. The result was excellent; the apple was cleaned perfectly of soot, even of that within the cavity. After this success, other washing solutions were tried with the same 30-second brushing technique. These solutions, numbered consecutively with the earlier trials, are as follows:

15. 0.25 per cent "BW" silicate solution at 110 degrees F.
16. 10 per cent "BW" silicate solution at 110 degrees F.
17. Same as 16, plus enough soap to form a good suds.
18. Same as 17, plus enough sodium hydroxide for N/8 solution.
19. Same as 18, except that the fruit was rinsed in 1 per cent hydrochloric acid plus Vatsol before the final rinse in water.
20. Soap and water at 110 degrees F.

With the exception of the 0.25 per cent "BW" silicate used in trial 15, all of the solutions tried cleaned the fruit remarkably well. The 10 per cent "BW" solution either with or without soap was not appreciably better than soap alone (trial 20). However, the addition of alkali

as in trials 18 and 19 was beneficial. No marked injury to the fruit resulted from any of these brushing trials.

Since the alkali-reinforced silicate solutions seemed most promising, two other sodium silicates, the "Metso" and "Metso 99" brands, which are more alkaline than the "BW" brand, were obtained from the Philadelphia Quartz Company. Each of these silicates was tried in 1, 5, and 10 per cent solutions at 110 degrees F, both with and without soap, using the 30-second brushing technique. The fruit was very well cleaned by every one of the solutions. The 1 per cent solutions were as effective as the higher concentrations, and the addition of soap made no improvement. The "Metso" solutions were as effective as those of the "Metso 99", which is more alkaline than "Metso". Both silicates at any of the concentrations tried seemed to be somewhat better than a soapy 10 per cent "BW" silicate solution. No injury to this fruit of the Willow Twig variety followed the treatment with these silicates.

All of the brushing trials emphasized the fact that brush facilities in addition to the rubber brushes in the Bean Model E machine would be necessary to clean the fruit effectively. For this reason a Bean No. 7 two-way cleaner was installed in the washer-grader train immediately after the Bean Model E underbrush-flood washer. The No. 7 cleaner consists of a series of nine hair brushes or rollers over which the fruit moves. Above the brushes is a series of four rollers to which pieces of cloth are attached so that their ends are free to wipe against the apples as they pass over the brushes. The ends of the cloths become unravelled as they revolve so that threads drop off gradually and thus maintain fairly clean wiping surfaces.

Because the "Metso" brand silicate seemed promising in the laboratory trials, it was also tried in the Model E machine after the two-way cleaner had been added to the washer-grader train. For comparison, "BW" silicate solutions, hydrochloric acid, and acid-Vatsol solutions were also tried.

The solutions tested were as follows:

- A. 1 per cent hydrochloric acid at 80 degrees F.
- B. Same as A, plus just enough Vatsol powder (2 or 3 ounces) to cause foaming.
- C. Soapy 1 per cent "BW" silicate at 105 degrees F.
- D. Soapy 5 per cent "BW" silicate at 95 degrees F.
- E. Soapy 10 per cent "BW" silicate at 80 degrees F.
- F. Soapy 1 per cent "Metso" silicate at 110 degrees F.
- G. Soapy 5 per cent "Metso" silicate at 95 degrees F.
- H. Soapy 10 per cent "Metso" silicate at 80 degrees F.

As facilities for heating water were inadequate, it was impossible to maintain the washing temperature while increasing the concentration of the materials. This fact accounts for the temperature differences.

The No. 7 two-way cleaner was so effective that all of these solutions worked exceptionally well as compared to the previously poor result with the washing machine alone. However, the acid and acid-Vatsol solutions (trials A and B) were least effective. The Vatsol improved the wetting of the apples in the Model E machine, but did not appreciably increase the removal of the soot in the stem ends by the two-way

cleaner. All of the "Metso" solutions (trials F, G, and H) were alike in effectiveness but were inferior to either the 5 or 10 per cent "BW" solutions (trials D and E), contrary to the indications in the laboratory tests. The 1 per cent "BW" solution (trial C) was relatively ineffective, but still was better than the acid solutions though inferior to the "Metso" solutions. The soot in the stem ends, as usual, was the most difficult to remove. The fact that the 5 and 10 per cent "BW" solutions loosened the soot in the cavity most effectively probably accounts for the superiority of these solutions. Both brands of silicate removed only partially the waxy coat of the apples, which fact accounts for their superiority to the acid or acid-Vatsol solutions. Aside from its greater effectiveness in cleaning the fruit, the "BW" brand has an advantage in that solutions of it are more readily prepared than solutions of the "Metso" brand. The "Metso" silicate is a granular solid, which seems to dissolve slowly, whereas the "BW" brand is a heavy, viscous liquid which is readily miscible in a small amount of water. Also, the "Metso" solutions attacked the acid-proof asphalt paint with which the wash tank is treated.

The results show that a 5 or 10 per cent "BW" silicate solution at 80 degrees F in a Bean Model E underbrush-flood washer followed by the Bean No. 7 two-way cleaner is effective in the removal of soot such as is found on Willow Twig apples in the bottom land orchards along the Ohio River in the northern panhandle of West Virginia. The addition of enough soap to cause a slight suds is believed to be advantageous. A 10 per cent "BW" silicate solution is recommended in preference to a lower concentration since the matter of spray residue removal must be considered. The higher concentration should prove more effective in this respect. Also, a temperature of at least 80 degrees F should be used to facilitate the removal of both spray and soot residue. As the fruit in the problem orchard has never in the past carried a spray residue load much above the previous tolerance for lead of .018 grains per pound, no difficulty is expected in reaching the new tolerance of .025 with a 10 per cent "BW" silicate solution at 80 degrees F. Indeed, it seems likely that if the soot is removed effectively, it should prove a visible criterion of spray residue removal.

It is possible that other varieties of apples might require less energetic methods of soot removal. However, it is felt that since the Willow Twig is the leading variety in the district, and since it would appear to be at least as difficult to clean in every way as the other standard varieties, the materials and technique involved should be generally applicable.

Common storage tests in which the washed Willow Twig apples were stored under like condition with unwashed fruit have shown no appreciable decrease in the expected length of storage life. Under good common storage conditions the Willow Twig does not reach its maximum culinary quality until March.

#### ACKNOWLEDGMENT

For their interest in the solution of this problem, the authors acknowledge the cooperation of the Philadelphia Quartz Company, the John Bean Manufacturing Company, The National Oil Products Company, and the American Cyanamid Company.

# The Influence of Certain Nutrient Conditions on Catalase Activity of Apple Seedlings

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IT has been shown that an increase in catalase activity is sometimes associated with an increase in growth and other vital phenomena (1, 2, 3, 4, 5).

The object of the study recorded in this paper was primarily to gain some idea of the usefulness of a simple catalase determination in reflecting the vigor and growth response of apple seedlings as affected by mineral nutrition.

## MATERIALS AND METHODS

McIntosh seeds germinated in peat moss were selected for uniformity of size and vigor and transplanted to 2-gallon glazed crocks filled with clean moist sand. Fifty pots of nine seedlings each were started. Hoagland's nutrient solution was supplied to the cultures at regular intervals until the seedlings were about 3 inches high. At this time the crocks were divided into four series each of which consisted of 10 or more pots. Three of the series were flushed with distilled water and subsequently supplied with various deficiency solutions. One series received minus nitrogen solution, another minus potassium and the third was supplied with a solution lacking phosphorus. The remaining seedlings continued to receive the full nutrient treatment.

The nutrient solution was diluted to one-fourth its specified strength and supplied at the rate of 2 gallons per pot per week by means of a drip system. A hole plugged with glass wool at the bottom of the pots provided free drainage of the cultures. Once a week all the crocks were flushed with 2 liters of distilled water, followed immediately by the nutrient solution.

Two months after the experiment was started, six pots in each of the three deficiency series were supplied with full nutrient solution the same as the check plants. The four remaining pots in each treatment continued to receive the deficiency solutions.

At various intervals throughout the experiment samples of leaf tissue were taken and catalase activity determined. A composite sample consisted of leaves from designated regions of five or more representative plants in each treatment. Duplicate composite samples were taken and the results usually agreed very closely. The standard method adopted for determining catalase activity was similar to that described by Heinicke (6).

## RESULTS

As indicated in the Table I, the trend in the full nutrient plants was toward an increased activity throughout the experiment with a slight decrease near the end. This was accompanied by thrifty vegetative growth in which many dark leaves were produced on good terminal and lateral growth.



TABLE I—CATALASE ACTIVITY OF APPLE SEEDLINGS UNDER VARIOUS NUTRITIONAL CONDITIONS  
(SECONDS REQUIRED TO LIBERATE 3cc O<sub>2</sub> FROM 2cc OF 10 Vol. H<sub>2</sub>O<sub>2</sub>)

Date of Sampling* 1938	Location of Tissue	Full Nutrient	Minus Nitrogen	-N† to F.N.	Minus Potassium	-K† to F.N.	Minus Phosphorus	-P† to F.N.	Remarks
April 5	Lowest leaf	168	450	—	300	—	208	—	-N plants begin to show deficiency symptoms. No deficiency symptoms in other plants. Full nutrient plants more vigorous than deficiency plants.
April 7	Second lowest leaf	158	450	—	270	—	163	—	
April 19	Third lowest leaf	142	540	—	234	—	168	—	
April 28	Fourth lowest leaf	92	1080	—	216	—	270	—	-N plants very chlorotic. -K plants begin to show deficiency symptoms. -P plants, no deficiency symptoms, retarded growth. F.N. very vigorous and thrifty. Deficiency symptoms more apparent in -N & -K. No deficiency symptom in -P. Growth retarded in all deficiency series. F.N. very vigorous.
May 5	Fifth lowest leaf	91	1800	—	270	—	317	—	
May 18	Sixth lowest leaf	78	1350	360	360	174	385	234	
May 26	Eighth lowest leaf	78	1800	174	360	158	385	174	-P begin to show deficiency symptoms. -N Very chlorotic. Necrotic areas begin to appear. -K pronounced deficiency symptoms. All deficient to F.N. plants show signs of revival. Deficiency plants in very poor condition. F.N. very large and vigorous.
June 9	Terminal leaf	101	5400	101	208	101	284	90	
June 21	Terminal leaf	120	6000 +	112	216	108	360	101	
June 29	Terminal leaf	103	6000 +	101	384	101	416	91	Deficient to F.N. plants regaining vigor very rapidly. Deficient plants show very severe deficiency symptoms. F.N. check. Very vigorous.
Average dry weight (gms) per plant at end of experiment		9.90	1.13	270	1.80	3.60	1.89	4.50	

\*Treatments started March 8th, 1938.

†Treatments shifted May 7th, 1938.

The catalase activity of the nitrogen deficient plants decreased very rapidly until about a month before the experiment ended when it was absent. Little or no growth was produced by plants in this series. The leaves present at the outset became chlorotic soon after the treatment was started, and later on brown necrotic areas appeared on the margins and tips of many of the leaves.

The potassium deficient plants showed a similar trend in catalase activity, but to a lesser degree than the seedlings lacking nitrogen. The reduction in catalase activity was observed before any deficiency symptoms were apparent. Growth, however, was definitely retarded. No new leaves were produced and only a slight gain in dry weight resulted during the experiment. The characteristic marginal and tip "scorch" and other deficiency symptoms appeared about 6 weeks after the treatment was started and became more apparent as time went on.

The seedlings lacking phosphorus were the last to show any appreciable difference in catalase activity and growth response. However, a significant reduction in the enzyme activity became apparent about 6 to 7 weeks after the treatment was started and this corresponded with a retardation in growth. The catalase activity was reduced before any symptoms were apparent.

The results of the catalase determinations of the plants shifted from deficiency to full nutrient treatment showed a marked increase over that of the continuously deficient seedlings a week after the new treatment was begun. The activity of the enzyme in these plants increased as time went on until a point was reached where their catalase value was as high as the full nutrient check plants regardless of previous treatment. Along with the increase in the ability of the tissue to decompose hydrogen peroxide, there was a corresponding revival of vegetative activity. At the time the experiment was terminated no deficiency symptoms were apparent on the new vigorous and healthy growth produced.

### CONCLUSION

It is evident from an examination of the data that a deficiency of any of the three major elements tends to reduce catalase activity. Lack of nitrogen seems to have the most rapid and most profound influence in depressing the activity of the enzyme. While potassium and phosphorus deficiencies sooner or later depress catalase activity, neither of these two elements seem to have as potent an influence on the enzyme-catalase as does a deficiency of nitrogen. It is interesting to note the rapid increase in catalase activity of the leaf tissue shortly after nitrogen, phosphorus and potassium were supplied to the plants deficient in these elements.

Catalase activity seems to be easily influenced by factors that affect the nutritive or physiological condition of the tissue. While we are still in the dark as to the metabolic function of catalase and the real significance of the catalase test, the preliminary results of these tests have been very suggestive but more work concerning the use of the enzyme as an indicator is necessary.

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## A Comparison of Wetting Agents in Apple Washing<sup>1,2</sup>

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CONFLICTING evidence has been presented in recent years on the value of wetting agents in the washing of apples (1, 2, 3, 4, 5, 6, 7, and 8). Following a report in 1934 (1), which indicated that considerable advantage could be gained by the use of certain wetting agents, further work was done at the University of Maryland in 1935, 1936, and 1937 in the testing of wetting agents, added to acid washing solutions. In the previous report it was shown that some wetting agents were ineffective or even injurious to the fruit, whereas others were quite effective in aiding in the removal of the lead residue. The possibility of more effective agents, as well as a consideration of possible seasonal and variety differences, led to these further studies which are actually part of a larger project on apple washing, carried on cooperatively between the Department of Horticulture, University of Maryland, and the Bureau of Plant Industry, United States Department of Agriculture.

As in the earlier work, several wetting agents were furnished by the manufacturers, used at a concentration of 1 per cent in a hydrochloric acid solution of 1½ per cent. A flotation washer again was used and the same temperatures (60 to 70 degrees F and 100 degrees F) of the washing solution were employed. As noted in Tables I and II, York Imperial and Stayman Winesap varieties were obtained in any given year from two spray plots which received five to seven cover sprays of lead arsenate, 3 pounds per 100 gallons, with the addition of mineral oil to certain of the covers for one of the spray plots. Bordeaux mixture 2-4-100 was in all of the cover sprays. It is apparent that with such spray programs a fairly heavy residue of lead would be found at harvest, as can be seen in the tables, although five covers in 1937 resulted in more residue than seven covers in 1936. Results of 1935 are not presented at this time, but are in agreement with results of 1936 and 1937. Samples of fruit were obtained from two trees in each spray plot, keeping the fruit from each tree separate for washing treatments and analysis. A random lot of 60 fruits was taken from each tree sample for any given washing treatment, such as a certain wetting agent at a given temperature. Each lot of 60 apples was further subdivided after treatment into two lots for chemical analysis, thus each analysis was made on 30 apples. Since two trees from each spray plot furnished two lots each for chemical analysis for any washing treatment, the figures in Tables I and II represent the averages of four analyses on random lots of apples, except for Stayman in Table I where two analyses were averaged.

<sup>1</sup>Scientific Contribution No. 486, Department of Horticulture, Maryland Agricultural Experiment Station.

<sup>2</sup>The cooperation of Mr. Edwin Gould, University of West Virginia, is acknowledged in connection with the conduct of work on the spray plots.

TABLE I—LEAD RESIDUE ON YORK AND STAYMAN APPLES AS AFFECTED BY WETTABLE AGENTS USED IN WASHING MEDIUM, 1936 (LEAD IN GRAINS PER POUND OF APPLES)

Spray Treatment	Temperature of Wash (Degrees F)	No Washing	HCl 1.5 Per Cent Only	Wetting Agents					Average for all Wet-ting Agents
				Vatsol	Nac-conal-E	Aresket	Gras-selli-A	Tergitol	
York Imperial									
7 covers lead	70	.063	.020	.013	.016	.014	.016	.013	.015
arsenate	100	.063	.030?	.012	.014	.011	.009	.010	.011
7 covers lead	70	.119	.033	.017	.027	.018	.027	.027	.023
arsenate plus mineral oil in 5, 6, and 7	100	.119	—	.014	.019	.013	.014	.019	.015
Stayman Winesap									
7 covers lead	70	0.62	.018	.010	.011	.012	.011	.014	.012
arsenate	100	0.62	.012	.007	.008	.007	.006	.006	.007
7 covers lead	70	.105	.028	.012	.018	.021	.019	.013	.016
arsenate plus mineral oil in 5, 6, and 7	100	.105	.018	.008	.008	.008	.006	.006	.007

*By Analysis of Variance of Data for Wetting Agents:*

Between wetting agents = significant exceeding 5 per cent point.

Between varieties = significant exceeding 1 per cent point.

Between temperatures = significant exceeding 1 per cent point.

Between spray treatments = significant exceeding 1 per cent point.

Interaction wetting agent X varieties = significant exceeding 5 per cent point.

Interaction wetting agent X temperatures = significant exceeding 5 per cent point.

Interaction varieties X sprays = significant exceeding 1 per cent point.

Interaction temperature X sprays = significant exceeding 1 per cent point.

Standard error of difference between means shown in table = .0014 for York and .0019 for Stayman.

TABLE II—LEAD RESIDUE ON YORK APPLES AS AFFECTED BY WETTING AGENTS USED IN WASHING MEDIUM, 1937

Spray Treatment	Temperature of Wash (Degrees F)	No Washing	HCl 1.5 Per Cent Only	Wetting Agents				Average of All Wet-ting Agents
				Aresket	Grasselli	Tergitol	Santo-merse	
5 covers of lead	70	.081	.033	.018	.014	.016	.015	.016
arsenate								
5 covers of lead	70	.171	.050	.022	.019	.028	.021	.023
arsenate + mineral oil in 4 and 5								

*By Analysis of Variance of Data for Wetting Agents*

Between wetting agents = significant exceeding 1 per cent point.

Between spray treatments = significant exceeding 1 per cent point.

Standard error of difference between means in table = .0035.

The method of analysis for lead determinations was the dithizone method (2), as modified by C. R. Gross, C. W. Murray, and C. C. Cassil, United States Department of Agriculture. Some analyses made by the United States Department of Agriculture on some duplicate lots of apples were in agreement with the Maryland results.<sup>3</sup>

<sup>3</sup>Analyses were made by Dr. Paul A. Parent, chemist in the Department of Horticulture, University of Maryland.

## RESULTS

In Tables I and II, an appreciable value of adding wetting agents to 1.5 per cent hydrochloric acid solutions used for removal of lead spray residues, is quite definitely shown both with usual room temperatures and with higher temperature (100 degrees F) of the washing solution under the conditions of use in a flotation type of machine. Although the initial residue on the unwashed fruit was higher in 1937 than in 1936, it is seen that the *average* remaining residue following the use of wetting agents on York apples at room temperatures, was practically the same, namely, .015 and .023 for 1936 versus .016 and .023 for 1937. At either temperature, all wetting agents were about equal in effectiveness on apples which received lead arsenate covers *without* mineral oil, but when mineral oil was included on the spray program, some differences appeared in the relative effectiveness of the several wetting agents, varying somewhat with variety. Vatsol was most consistently effective under all conditions. With oil-sprayed York apples, Tergitol was less effective than Vatsol at both temperatures, but with oil-sprayed Stayman, Tergitol was equal to Vatsol. Values for Aresket were similar to Vatsol except at room temperature with oil-sprayed Stayman. Nacconal-E and Grasselli-A, under similar conditions with York as well as Stayman, likewise were less effective than Vatsol, but equalled it under other conditions.

Apparently variety differences, temperatures, and differences in spray programs may affect the efficiency of any wetting agent. Comparing varieties in Table I, it appears that comparable washing treatments reduced the lead residue on Stayman in 1936 more than on York. Raising the temperature of the washing solution, of course, increased the efficiency of all treatments but was more marked in this effect with apples receiving an oil-spray. For all wetting agents, raising the temperature for washing *oil-sprayed* fruit reduced the lead residue on York by 35 per cent and on Stayman by 56 per cent, compared with reductions of 27 per cent and 41 per cent with fruit not sprayed with oil. The greater value of wetting agents for use on oil-sprayed fruits is recognized in other reports on wetting agents, particularly at higher temperatures. However raising the temperature of all washing solutions was more effective with the Stayman variety than with the York, even though there was much less development of wax on the Stayman variety.

Considering the seasonal differences, it is interesting to note that seven cover sprays on York in 1936 did not result in as much residue at picking time as five sprays of 1937; however, removal was aided much more by wetting agents in 1937 than in 1936. Again the difference in wax development in the two seasons may be related to these differences.

## CONCLUSIONS

Certain wetting agents can be used effectively in aiding the removal of lead residues from apples in a flotation type of washer, either at usual room temperatures, or at 100 degrees F. If oil is used in late

cover sprays, benefit of wetting agents is greater in heated than in unheated solutions. All wetting agents are not equally effective under all conditions, and the *relative* results may be influenced somewhat by variety of apple, and temperature of the solution.

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# Carbon Dioxide Assimilation of Apple Leaves on "Thin" and "Thick" Wood<sup>1</sup>

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IT is generally accepted that large and well-developed apple fruits are usually borne on vigorously growing trees producing a large amount of thick new wood. Some investigators (6) have based a new system of pruning on the thickness of the wood. This so-called "thin wood" pruning involves the removal of all branches having a diameter of 0.25 inch or less in the 4-year wood. Larger branches, no matter how numerous, are all left in the tree. The rate of food manufacture by leaves on thin wood has been considered to be so low as to render such leaves useless to the tree. It has been demonstrated (3) that apple branch tissue of small diameter offers considerable frictional resistance to the flow of water, and this fact might support the assumption of a low rate of food manufacture by leaves on such branches. It has also been shown that the position of a leaf in the tree greatly influences the amount of light available to it (2). Most leaves on thin wood are not well exposed to light, and it is suggested that this may be the major factor influencing the rate of food manufacture.

## MATERIALS AND METHODS

The gas analysis apparatus developed by Heinicke and Hoffman (4), and used in studying the influence of various factors (1, 5) upon the carbon dioxide assimilation of apple leaves was used in this study, except that a separate air meter was used for each leaf. Preliminary results involving a larger number of leaves but secured using the usual method of calibration indicated that high assimilation rates might be expected from leaves on thin wood. The apparatus was set up in the College Orchard near a 25-year-old McIntosh tree in a vigorously growing condition.

Assimilation runs of 4 hours' duration were made between 8:00 a.m. and 1:00 p.m. The leaves were enclosed in cellophane bags during the period of the run. The temperature of the air, sky conditions, and the light intensity, were recorded at the beginning, the middle, and the end of each run. A Weston illuminometer was used to record light intensities. The target was placed on top of each leaf parallel to its surface. The maximum light available at the time was recorded by turning the target toward the sun.

The average diameter of branches in the 4-year-old, or 1935 wood, was taken as the criterion for classification as thin or thick wood. Branches with a diameter of 0.25 inch or less were called thin wood. Usually terminals on such branches were short and slender. Leaves were selected on the different types of wood. In some cases they were adjusted so that they received more nearly equal light. Leaves on thin

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wood usually received less light than those on the thick wood. The leaves used in this study were, in most cases, spur leaves originating on 1935 or 1936 wood. The branches bearing the leaves were always in the same portion of the tree. A comparison of the length growth of the branches bearing two of the tested leaves shows much greater growth on the thick branch: 1925, 5.8 vs 13.5 inches; 1936, 3.0 vs 9.8 inches; 1937, 1.3 vs 16.7 inches; and 1938, 0.4 vs 8.2 inches.

For the first series two leaves were selected, both of which received reasonably good illumination, but the supporting wood in one case was only 0.15 inch in diameter in the 1934 wood. Carbon dioxide assimilation runs were made for 5 days, between June 23 and July 1. The data presented in Table I indicate that a leaf on thin wood may assimilate an appreciable quantity of carbon dioxide. While the rate of assimilation does not equal that of the leaf on thick wood, it does better than the factor of wood size would indicate.

TABLE I—CARBON DIOXIDE ASSIMILATION OF TWO MCINTOSH LEAVES  
(EXPRESSED AS MILLIGRAMS CO<sub>2</sub> PER 10 IN<sup>2</sup> PER HOUR)

Type Fourth Year Wood	Leaf Number	June 23	June 24	June 27	June 29	July 1
Thin .....	1	18.75	16.90	-6.04	23.96	10.28
Thick .....	2	26.07	20.26	-8.79	34.46	19.13
Weather .....	—	Overcast foggy	Cloudy	Rain	Cloudy	Cloudy

In the second series, the leaf on the thin wood usually received slightly less light than did the leaf on thick wood during the first part of the run. The data in Table II indicate that a leaf on thin wood may assimilate almost as much carbon dioxide as one on thick wood. On August 1, the leaf on thin wood was pulled into a position so that it received considerably more light than the leaf on the thick wood. These data are presented in Table III and show a marked increase in the relative assimilation rate of the leaf on thin wood. It would appear that in this case, at least, light was a limiting factor. Under more favor-

TABLE II—CARBON DIOXIDE ASSIMILATION OF TWO MCINTOSH LEAVES  
(EXPRESSED AS MILLIGRAMS CO<sub>2</sub> PER 10 IN<sup>2</sup> PER HOUR)

Type Fourth Year Wood	Leaf Number	July 16	July 21	July 25	July 27	July 28	July 29	July 30
Thin .....	3	14.69	22.35	11.94	26.69	23.72	23.04	14.62
Thick .....	4	14.82	19.41	11.93	26.76	22.36	25.06	16.03
Weather .....	—	Clear	Overcast rain	Overcast	Cloudy	Haze	Cloudy	Partly cloudy

TABLE III—CARBON DIOXIDE ASSIMILATION OF TWO MCINTOSH LEAVES  
(EXPRESSED AS MILLIGRAMS CO<sub>2</sub> PER 10 IN<sup>2</sup> PER HOUR)

Type Fourth Year Wood	Leaf Number	August 1	August 3	August 4	August 6	August 9	August 10
Thin (light increased) .....	3	33.97	30.71	36.58	40.71	36.90	37.35
Thick (light as in Table II) ..	4	31.08	25.08	20.69	27.36	27.50	21.96
Weather .....	—	Overcast	Clear	Clear	Haze	Clear	Clear

able light conditions the rate was very much higher than before the change in position.

A third set of leaves was selected so that the one on thin wood had considerably less light than the one on thick wood. The assimilation rates secured were, therefore, surprising. Table IV presents data showing a consistently higher assimilation by the leaf on thin wood.

TABLE IV—CARBON DIOXIDE ASSIMILATION OF TWO MCINTOSH LEAVES  
(EXPRESSED AS MILLIGRAMS CO<sub>2</sub> PER 10 IN<sup>2</sup> PER HOUR)

Type Fourth Year Wood	Leaf Number	August 18	August 22	August 23	August 24	August 25	August 26
Thin.....	5	20.18	27.85	28.39	25.43	32.90	26.27
Thick.....	6	14.89	19.67	20.40	18.19	20.74	20.60
Weather.....	—	Cloudy	Clear	Clear	Partly cloudy	Clear	Partly cloudy

### DISCUSSION

These data indicate that a normal leaf on thin wood may assimilate carbon dioxide at a rate equal to or greater than a similar leaf on thick wood. It appears from these data that the thickness of the wood has little influence on the assimilation rate and cannot in itself account for the poor, spindly growth in succeeding years. It is suggested that light is a determining factor controlling the carbon dioxide assimilation of these thin wood leaves in some instances. An examination of these data does not, however, indicate that light or wood thickness accounts for some of the assimilation rates noted.

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# Transpiration of Lemon Cuttings with Reference to Leaf-Root Relationship

By J. B. BIALE, *University of California, Los Angeles, Calif.*

TWO lines of approach were undertaken in the study of the relationship between conditions affecting the intake and the loss of water by rooted Eureka lemon cuttings. One aspect of this problem dealing with changes in the absorbing root surface and with the effects of the temperature of the medium containing the roots on transpiration has been reported previously (1). In the second phase, included in this communication, the same plant material, the same controlled environmental conditions and the same measuring instruments were used as in the previous study with the exception that changes in the transpiring surface took the place of root pruning. Ordinarily one leaf has been removed at a time and transpiration losses recorded for at least 2 days, while constant external conditions and a constant non-limiting root temperature of 25 degrees C were maintained in all tests. Since the plant material and methods for this work were essentially the same as for the study on root surface effects, I shall limit the discussion of the experimental procedure to several features not taken up heretofore.

## VARIABILITY OF DAILY WATER LOSS

Since the cuttings were taken from terminal shoots of the last mature flush of growth, the maximum age of the plants at time of planting was 6 months, but difficulties were experienced in selecting plants of exactly the same age. This situation, coupled with the fact that cuttings were removed from several adjacent trees and from different positions on the tree, resulted in unavoidable variations between plants. In view of this variability, it appeared advisable to subject all the plants in a set to the same treatment at the same time, to determine the constancy of the water loss from day to day under the same conditions, and finally to compare the response of the entire set to reduction in leaf surface. Table I was compiled by counting the number of deviations of each reading from the average water loss for each plant subjected to the same environmental conditions.

Of the experiments summarized in this table, No. 1 was concerned with root removal, No. 2 with humidity effects at a constant root temperature, Nos. 3 and 4 with leaf removal, and No. 5 with root temperature influences. In spite of the diversity of treatments and conditions

TABLE I—NUMBER OF VARIATIONS IN DAILY WATER LOSS UNDER CONSTANT ENVIRONMENTAL CONDITIONS

Variation from the Mean (Per Cent)	Experiment Number					Total	Per Cent of Total
	1	2	3	4	5		
Less than 5 . . . . .	96	21	39	62	52	270	64.3
5 to 10 . . . . .	22	12	14	25	21	94	22.8
10 to 15 . . . . .	14	2	10	6	2	34	8.1
Over 15 . . . . .	4	1	7	8	3	23	5.4

included, 87 per cent of the readings show less than 10 per cent of variation from the mean. I wish to call attention to the chief reason for the high variability in 13 per cent of the remaining cases. With the exception of experiment No. 5, Table I comprises all the transpiration losses including the readings taken the first day after transfer from the greenhouse to the control chambers. It has been found that usually an adjustment of 1 or 2 days is required upon placing the plants under artificial light. If the data for this initial period be eliminated, which procedure is adopted in reporting this work, it appears reasonable to suggest that a difference in water loss of 10 per cent or more can be considered as due to treatment. Actually, in the experiments reported heretofore, I assumed 20 per cent as the minimum of a significant difference. Occasionally, though infrequently, large variations may be observed in a single plant in contrast to the normal behavior of the remainder of a series of 16. In such an exceptional case a progressive drop in water loss from day to day takes place irrespective of evaporating conditions. For some time no visible effect in leaf turgidity can be observed, but after several days the plant begins to wilt. In other words, a decrease of transpiration rate from the normal appears to indicate certain abnormal changes in the plant prior to any apparent effects.

#### EFFECT OF LEAF REMOVAL ON WATER LOSS

Transpiration losses were determined by weighing the plant and the sealed container prior to illumination and again 12 hours later, immediately after the lights were turned off. The leaves were removed right after the morning weighings, their fresh weights recorded and subtracted from the difference of the morning and evening weighings. It was of importance to find out at the outset whether there was any shock effect produced by leaf removal. In Table II the daily water loss

TABLE II—WATER LOSS PER PLANT IN GRAMS AND LEAF AREAS IN SQUARE DECIMETERS

Plant Number	Leaf Area	Water Loss		Leaf Area	Water Loss		Leaf Area	Water Loss	
		October 27	October 28		October 31	November 1		November 2	November 3
1	1.25	4.61	4.77	0.99	4.22	4.05	0.64	3.41	3.04
2	1.86	6.57	6.56	1.41	5.37	5.10	0.90	4.01	3.50
3	2.59	13.44	13.78	1.43	8.57	8.38	0.93	6.27	5.68
4	1.77	2.34	2.69	1.33	1.71	1.71	0.80	1.37	1.14
5	1.80	4.71	4.69	1.35	4.12	3.77	0.85	3.20	2.98
6	2.33	5.10	5.51	1.74	5.20	4.96	1.25	4.61	4.51
7	2.16	6.01	5.85	1.59	5.14	5.00	1.07	3.84	3.38
8	3.21	8.63	8.62	1.71	6.25	6.24	1.18	5.88	5.47
Average	2.12	6.43	6.56	1.44	5.07	4.90	.65	4.07	3.71

is given for 2 days subsequent to leaf removal. The data included here comprises only a small fraction of three series of experiments.

It is evident from Table II that the response to leaf removal was immediate and that the water loss for the first day following removal did not differ significantly from the quantity transpired during the second day. Comparing the reduction in leaf area with the decrease in

rate of transpiration, it can be seen that the former dropped more sharply than the latter. Upon removal of 32 and 33 per cent of the foliage the amount of water lost decreased 23 and 22 per cent, respectively. Hence, if one should express these transpiration results per unit leaf area, a progressive increase could be observed. This behavior will be still more apparent in the experiments described below.

### WATER LOSS WITH REFERENCE TO LEAF POSITION ON STEM

In order to find out whether the order of leaf removal influences the rate of transpiration a set of 16 plants was divided into two groups. In Group A the basal leaf was removed first and then progressively up the stem, while in Group B the reduction in foliage took place from up down. The number of leaves per cutting varied from four to nine, but comparable plants were distributed among the two groups. Other-

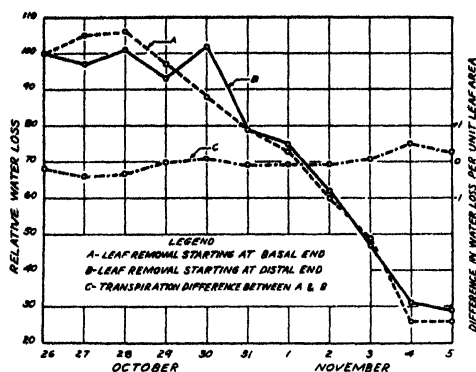


FIG. 1. Effect of the order of leaf removal on the rate of transpiration of Eureka lemon cuttings.

wise, both sets were subjected to the same conditions. Fig. 1 presents the relative water loss for each of the two groups by assuming the loss on October 26 for each set as 100. There is evidently no significant difference between the rate of transpiration of A and B. Any appreciable difference should have shown up most strikingly towards the end of the experiment, since by that time there was only one leaf left on each plant, the lowest in Group B and the uppermost in A. Graph C depicts the difference in actual water loss per unit area between A and B and shows that the fluctuations from the zero line are small. Maximov (2) points to the variations in structure and physiology of individual leaves at different levels on the same shoot, and suggests that under normal conditions the intensity of transpiration of upper leaves is higher than that of lower. The evidence available so far seems not to support this view. It might be that this discrepancy is due to the difference between Maximov's plant material and the Eureka lemon cutting.

### TRANSPIRATION IN RELATION TO LEAF-ROOT RATIO

In much of the work on water relations of plants the unit leaf area has been used as a basis for comparison. This has been done with justification in view of the fact that the leaf is the active transpiring surface, but perhaps not sufficient attention has been paid to conditions under which it is questionable whether this unit is satisfactory. I have pointed out previously that the decrease in water loss does not go hand

TABLE III—TRANSPIRATION LOSSES FOR THE PERIOD OF ILLUMINATION  
(GRAMS PER SQUARE DECIMETER OF LEAF AREA)

Plant Number	Leaf Area	Water Loss	Leaf Area	Water Loss	Leaf Area	Water Loss	Leaf Area	Water Loss	Leaf Area	Water Loss
1.....	1.99	1.24	.92	2.18	.92	2.55	.49	4.29	.49	4.89
2.....	1.91	1.17	.80	2.78	.31	6.10	.31	7.29	.31	7.84
3.....	1.89	1.92	1.86	3.45	.84	4.63	.42	7.11	.42	7.18
4.....	1.63	2.75	.85	5.39	.43	6.57	.43	7.43	.43	7.69
5.....	1.99	1.82	1.99	2.38	1.48	2.97	.98	3.64	.45	4.83
6.....	1.53	1.81	.87	3.87	.42	6.16	.42	6.02	.42	5.83
7.....	1.31	2.25	1.31	3.25	1.00	3.86	.71	4.87	.33	6.05
8.....	1.96	1.41	1.83	2.43	.88	3.22	.40	4.28	.40	5.06
9.....	1.88	1.37	.91	3.07	.43	4.81	.43	5.47	.43	5.81
10.....	1.53	2.09	1.16	3.59	.73	4.81	.38	5.10	.38	5.47
11.....	2.58	2.48	2.58	3.42	1.82	4.31	1.15	4.68	.51	4.87
12.....	2.30	2.97	1.70	4.62	1.70	4.45	1.12	4.41	.62	4.80
13.....	1.90	2.38	1.90	3.49	1.39	3.62	.96	4.05	.53	3.55
14.....	2.22	1.66	1.02	3.77	.37	6.36	.37	6.58	.37	6.71
Average..	1.90	1.95	1.34	3.41	.91	4.60	.61	5.38	.44	5.70

in hand with the drop in leaf area. In Table III another experiment is cited in which this contention is born out more fully.

Considering the averages for the entire set of plants, it is to be noted that an increase in water loss of 75, 35, 12, and 10 per cent paralleled a decrease in foliage area of 29, 32, 33, and 28 per cent respectively. In other words, an approximately uniform reduction in leaf surface was responsible for an initial high rise in water loss followed by progressively smaller increases. This behavior was observed in the experiment in which root surface was limiting, but not in those with abundant roots. When the relationship between top and root is such that the leaf area in square decimeters per gram of root dry weight is higher than eight, transpiration per unit area increases with leaf removal. On the other hand, a reduction in foliage at ratios lower than five does not alter the rate of water loss significantly. A complete picture of the interrelation of the transpiring and absorbing surface is given in Fig. 2, in which the results of several experiments are averaged and the extent of leaf surface computed for each gram of root dry weight. The use of root weight instead of root surface is justified on the basis of a previous finding (1), in which it was established that with the freshly rooted cuttings a direct relationship exists between surface and weight. The limiting leaf area of 5 to 8 square decimeters per gram of root or, in terms of reciprocal values, of 130 to 170 milligrams of root weight per square decimeter of leaf area compares closely with limiting root surfaces as found by means of root

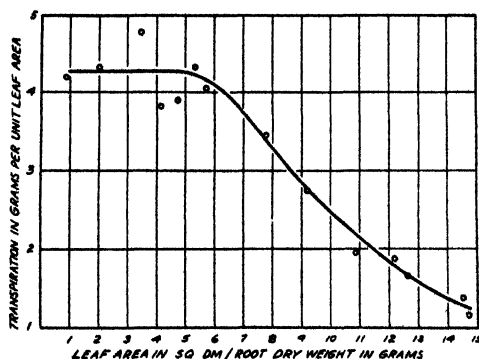


FIG. 2. The relation of transpiration per unit leaf area to the leaf-root ratio.

removal or by observations of plants with widely varying root surfaces. However, it should be emphasized that these values may change for different sets of conditions and for different plant materials.

Considering the water balance between top and root, it is of importance to note the condition of the plants with high leaf area-root weight ratios. The cuttings of the experiment presented in Fig. 1 wilted on October 26, 27, and 28 when the leaf surface-root weight ratios were 11.8, 9.1, and 9.1, respectively. They recovered fully the following day when this ratio was reduced to 8.3. In another experiment (recorded in Table III), pronounced wilting was observed at a ratio of 9.2 recovery at 7.8, though signs of low turgidity in three plants were noticed even at 5.7. Evidently there is a range of values, rather than a definite ratio, above which the water absorbing system is inadequate in supplying the transpiring surface.

#### CONCLUSIONS

Effects of leaf removal on transpiration of rooted lemon cuttings under constant environmental conditions and at constant root temperature were studied. Determination of the variability of the plant material showed that differences of water loss greater than 10 per cent could be considered as due to treatment. Starting leaf removal from the distal end resulted in about the same rate of water loss as beginning with the basal end. With root conditions non-limiting in relation to transpiring surfaces, comparisons in transpiration can be made on leaf area basis. A range of values was suggested for leaf surface in square decimeters per gram of root weight above which water loss per unit area decreases with an increase of this ratio.

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## Starch in the Avocado Tree

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AS one phase of our study of irregular bearing of certain avocado varieties in southern California (3, 4) we are investigating the effect of fruiting upon the carbohydrate and nitrogen cycles in the tree. These studies are in the main quantitative. However, since starch is easily, and from certain standpoints, more satisfactorily determined by microchemical methods a preliminary determination of the starch cycle in bearing and non-bearing trees has been made using the microchemical technique.

Apparently the only previous studies of seasonal changes in starch content of avocado trees were made by students in our laboratory. Gee (2) studied fluctuations in starch content of material collected at Riverside at bi-weekly intervals between January 2 and April 14, 1928. As a result of this short study he suggested that in the avocado tree there was "but one long cycle in starch storage, a reduction during the entire growing season and an accumulation during the dormant period". Scivanos (6) also working with material collected at Riverside at bi-weekly intervals between September 2, 1930, and April 15, 1931, reported a minimum starch content between October 15 and December 21 and a maximum in February and March.

### MATERIALS AND METHODS

The conclusions presented in this paper are the result of a study of two lots of material. One series of collections involved whole trees, the other, branches from individual trees. We hoped that by checking the results of one series against those of the other to be able to take into account individual tree variability in the one case and the effect of removal of leaf surface in the other.

Between January 18 and December 3, 1936, 16 carefully selected 6-year-old Mexican seedling avocado trees, all progeny of the same parent tree, were excavated and prepared for chemical analysis. As each tree was fractioned, from 20 to 32 samples representing all parts of the tree were collected and preserved in alcohol. This material was subsequently sectioned, stained in IKI solution, mounted in glycerine and the starch content estimated by observation under the low power of a microscope. A second, less detailed but in some respects more satisfactory, method of estimation was also used. About a dozen stained sections representing various sized roots or branches were placed in water or glycerine in a Syracuse watch glass. Two such preparations were made for each tree, one containing sections from trunk and branches, the other sections from various sized roots. By observation against a white back-ground the relative amount of starch can readily be estimated. By arranging the dishes in relation to two axes, one representing date of collection and the other density of color on an arbitrary scale, the positions they occupy will determine a curve representing the seasonal trend in starch content. The curves presented in the accompanying figures were constructed in this manner. Several



colleagues confirmed our opinion regarding the location of the dishes thus minimizing the personal factor, always present in methods involving estimation of values.

The trees used in this study were large for their age and were growing vigorously. Although rather variable in foliage and fruit characters, they were, we believe, sufficiently uniform in growth, blossoming and fruit setting to satisfactorily portray the seasonal starch cycle. They set very little fruit in 1936 and may therefore be considered non-bearing trees.

Beginning in July 1935 and continuing into November 1936, branches about 2 centimeters in diameter at the basal end were collected at intervals of from 2 to 6 weeks, from two 14-year-old Fuerte trees in an orchard near La Habra. This material was studied as described above. The trees were located in adjacent rows about 40 feet apart and were therefore subjected to similar environmental conditions. Both were producing alternately small and large crops but in opposite phase at the time collections were begun. The yield behavior of the two trees for 9 years is indicated in Table I.

TABLE I—YIELD OF FUERTE AVOCADO TREES IN NUMBER OF FRUITS PER TREE

Tree	1928-29	1929-30	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36	1936-37
1-12 ....	629	5	697	81	600	202	1,402	15	Large
2-9 .....	139	264	224	570	0	635	90	909	Small

A freeze in January 1937 destroyed the 1936-37 crop. Prior to the freeze the crop on tree 1-12 was estimated as larger than the 1934-35 crop and that on tree 2-9 also larger than that of 1934-35 but still small, indicating that the alternation continued throughout the period of collections. Tree 2-9 was somewhat smaller than tree 1-12 which probably accounts for the smaller crops produced.

#### MICROCHEMICAL OBSERVATION AND DISCUSSION

Fig. 1 illustrates the starch cycle in the excavated trees. Smooth curves have been drawn through points obtained by estimation as described above. These curves represent the starch cycle in branches and roots more than one centimeter in diameter. Branches, and to a lesser degree roots, less than 1 centimeter in diameter were more variable in starch content than the larger units. This variation is probably due to inclusion in the sample of tissues of various ages; the localized effect of growth, and, in the case of small branches, to position in relation to an appreciable leaf surface. Variations in starch content of small branches were greater than we have observed in shoots of temperate zone deciduous trees, possibly because length growth is more localized than in the deciduous tree.

Considering the tree as a whole, an examination of Fig. 1 indicates that the maximum starch content occurs in midwinter and the minimum in late summer and autumn. Between the winter maximum and the autumn minimum there is a gradual decline in starch content. This period coincides with that of growth activity of the top. It apparently indicates a rate of utilization of carbohydrates greater than the rate of synthesis. When growth diminishes or ceases in the autumn the rate of

production apparently exceeds the rate of utilization, and starch is deposited, accumulating gradually until the winter maximum is again attained. This sequence is almost identical with that previously reported for the orange tree (1) and suggests that it may be a general condition for evergreen trees in subtropical regions.

We were unable to detect an appreciable delay in starch storage in roots as compared with branches, which is not in accord with the generally recorded observation that roots lag behind the tops in both accumulation and depletion of starch. This may be due to the fact that the trees were permitted to branch close to the ground and the roots were therefore not far removed from a large leaf surface. Ishibe (5, Fig. 7) illustrates a similar condition in *Pinus densiflora* in Japan. The rate of decline was however somewhat slower in the roots than in the branches possibly due to delay in growth activity of roots as compared with shoots. On this point we have no evidence.

The results of the study of individual branches of the Fuerte trees at La Habra are presented in Fig. 2. Tree 1-12, which was in the off-crop phase, bearing 15 fruits at the time collections were started in 1935, shows the typical curve for non-bearing trees illustrated in Fig. 1. It produced much new growth during that summer, blossomed profusely during the winter and spring of 1936 and set a heavy crop during the latter part of May and the first week of June. It produced very little new growth during the summer of 1936.

Tree 2-9 which matured 909 fruits (approximately 450 pounds) during the first year of collection shows a much lower starch content throughout the summer and autumn than the non-bearing tree. Apparently storage of starch during the autumn and early winter was reduced by the demands of the developing fruit. After the crop was harvested, during March and April, the starch content increased to a late maximum in May and June. This tree produced practically no new growth during the summer of 1936 while it was carrying a heavy

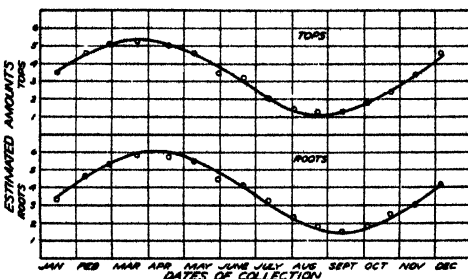


FIG. 1. Seasonal fluctuations in starch content of tops and roots of Mexican seedling avocado trees.

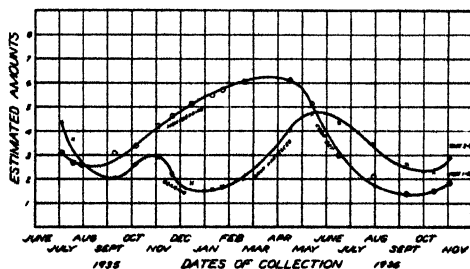


FIG. 2. Effect of fruiting upon fluctuations in starch content of two Fuerte avocado trees.

crop. The following spring it produced a late light bloom which was followed by much new growth.

Observations made upon material collected in other seasons and from other districts indicate that the periods of maximum and minimum starch content are not constant but fluctuate from season to season, depending upon environmental conditions, size of crop and time of harvest. During the current season the starch of Fuerte trees at Los Angeles declined until mid-November, which is approximately 2 months later than that indicated in Figs. 1 and 2 and corresponds with that recorded by Sclivanos (6) for material collected at Riverside.

Seasonal changes in starch content were gradual in all parts of the tree as previously noted for the orange (1). However the avocado seems to contain more starch at all times than the orange. Readily detectable quantities of starch were present, particularly in the primary xylem throughout the minimum period, whereas in the orange, during the corresponding period, frequently only a few scattered starch grains could be found. The roots contain relatively more starch at all times than branches of similar diameter.

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## Rolling of Leaves on Oriental Plum Trees, Apparently Caused by Cool Summers

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IN Berkeley, California, where the mean temperature between April 1 and October 31 is 58 degrees F or lower, leaves of many varieties of Oriental plums, *Prunus salicina*, *P. simonii*, and hybrids between these two species, roll inward upon their upper surfaces. Those of some varieties, such as Wickson, Kelsey, Simon, and Gaviota, form rather tight rolls, about as tight as those shown at the left in Fig. 1. Simon leaves seem to be most apt to roll: sometimes leaves formed in the coolest months are rolled somewhat, even at Davis, where the mean temperature between April 1, and October 31, is 10 degrees F or more above that at Berkeley.

Leaves of Climax, Satsuma, Becky Smith, Beauty, Sharkey, and Mariposa, roll less than those of Wickson and Simon in the average Berkeley summer, often about as much as those at the right in Fig. 1; but those formed in the coolest months of the coolest summers roll about as much as Wickson or Simon. Leaves of Formosa, Santa Rosa, Duarte, Apex, and Georgeson,

roll still less, failing to roll at all if formed during the warmest parts of a Berkeley summer. Leaves of Sultan roll slightly only if formed in the coolest parts of the coolest summers. Leaves of El Dorado, Inca, Discovery, Burbank, and Abundance, have not been observed to roll at all.

Leaves on potted trees of such varieties as Wickson will be like that shown in the center of Fig. 1, if grown in a warm greenhouse. Potted trees that are growing rolled leaves out of doors will grow normal leaves above the rolled ones on the same shoots, if the trees are taken into the greenhouse before summer growth has ceased.

Leaves of *Prunus maritima*, *P. subcordata*, *P. cerasifera* and several of its botanical varieties and hybrids, *P. domestica*, *P. insititia*, *P. Munsoniana*, *P. americana*, *P. nigra*, *P. spinosa*, *P. bokhariensis*, and *P. Besseyi* hybrids, have been observed for several years in Berkeley, and none have shown any rolling. In fact, among the species in many different families grown in Berkeley, the only symptom that resembled this leaf rolling, observed on any species except those comprising the



FIG. 1. At the left, badly rolled leaves; at the right, less compactly rolled leaves; and in the center, a normal leaf of the Oriental plum.

Oriental plums, was a folding upward of leaves on lilac bushes, especially bushes of *Syringa vulgaris*.

Oriental plum leaves have been examined repeatedly by entomologists and plant pathologists, but no evidence has been found to suggest that the rolling may be caused by an infestation or an infection. The explanation of the rolling that suggests itself is that the low summer temperature may reduce the growth of some marginal cells more than it reduces growth of cells nearer the midribs. No histological study has been made, however.

## The Effect of Potash on Leaf-Curl of Sour Cherry

By L. R. LANGORD, *University of Wisconsin, Madison, Wis.*

IT has previously been reported (3) that a characteristic leaf-curl of cherry which is quite common in the Door County region of northern Wisconsin is associated with root injury. The most apparent characteristic of the trees affected with this trouble is a curling of the leaves similar to that which might be expected from drought. Trees affected with leaf-curl were found not only to have a smaller percentage of live feeding roots, but also to have fewer large roots than trees with normal foliage. Roots from curl-leaf trees were in general of a darker color than those of normal trees. It was also reported that curl-leaf trees which had been mulched with straw showed less leaf-curl and a larger percentage of live feeding roots than comparable trees which had not been mulched but cultivated deeply.

Since this report was made fertilizer trials have shown that cherry trees affected with curl-leaf which had been fertilized with potash showed less leaf-curl and greater root and shoot growth than comparable trees which had not been fertilized (Fig. 1). The effect of the



FIG. 1. Photograph of branches and roots from sour cherry trees which were comparable before potash was applied. Branches and roots at right from tree which had received potash 2 years previous to the time picture was taken. Branches and roots at left from tree which received no potash. Note lack of feeding roots and curling of leaves at left.

straw mulch previously reported to have decreased the amount of leaf-curl may have been due to a number of causes. Under drought conditions, which have frequently prevailed during the summer months of the last few seasons, the increase in soil moisture under the mulch would make for more favorable growing conditions. With the rotting of the straw mulch, elements necessary for plant growth, such as potassium, would be liberated into the soil. The mulch in retarding or preventing freezing of the soil in the fall or early winter might also prevent

or minimize root injury due to winter cold. This might be particularly important in such a region as Door County, Wisconsin where the soil, especially where curl-leaf is found, is commonly very shallow. The favorable effect of mulch paper on curl-leaf of cherry which has been reported by growers may have been due to higher soil temperatures under the paper during the winter months.

The possibility that an element other than potassium might have been present in the muriate of potash which was used as a fertilizer and which might have been responsible for the improvement of the curl-leaf trees fertilized with it seems unlikely as badly curled cherry trees show general similarities to symptoms of potassium deficiency reported in apple and peach (1, 2). The marginal leaf scorch given as a symptom of potassium deficiency in the apple is somewhat similar to very advanced stages of leaf curl in cherry where dead leaf tips and margins occur. In peach, potassium deficiency has also been associated with rolling of the leaves. Then, also, the marked response of cherry curl-leaf trees which have been fertilized with barnyard manure would also serve as an indication that the potassium in the barnyard manure might be responsible for the improvement, in as much as barnyard manure is high in potassium.

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## A New Disease of Papaya in Hawaii

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A DISEASE of papaya (*Carica papaya*) new to Hawaii, was first seen in July, 1937, at Waialua and Lualualei on the island of Oahu, to which island the disease is, at present, apparently limited. Losses have ranged from 6 to over 30 per cent. Investigational studies were started in April, 1938.

Affected plants are badly stunted, and foliage is characteristically yellowed with the leaves crinkled and at the same time bent downwards and inwards. There is little necrosis except of the edges of very young leaves and the intervenal regions of older leaves. Usually only the upper two-thirds of a tree shows symptoms. Diseased leaves abscise rapidly, and 4 to 6 weeks after initial symptoms, only a few badly distorted and undersized leaves remain, clustered at the top. The leaves



FIG. 1. Diseased plant in field, two healthy plants, of same age, in background.

<sup>1</sup>Published with the approval of the Director, Hawaii Agricultural Experiment Station, Honolulu, T. H.



developed prior to symptom expression persist as a fringe around the base of the plant.

The petioles of diseased leaves are characteristically bent downwards at the point of attachment; healthy leaves are borne on petioles which leave the stem at an angle above the horizontal. Yellowed leaves show small necrotic lesions with yellow margins; the spots range in size from pinpoints to approximately  $\frac{1}{8}$  inch in diameter. The yellow haloes which impart to the foliage the yellowed appearance may be small or quite extensive.

Linear, darker-green than normal, slightly raised, hydrotic-like streaks may be present on any portions of the main stem of a diseased plant, and on the petioles of yellowed leaves. Streaking consistently precedes the appearance of yellowing. The streaks vary from  $\frac{1}{8}$  to 1 inch in length and from  $\frac{1}{32}$  to  $\frac{3}{8}$  inch in width. Fruits formed on diseased trees are undersized and "bleed" profusely. Bleeding, caused by insect punctures of the fruit, is sometimes found on healthy plants but in volume and extent the condition found here is abnormal.



FIG. 2. Close-up of a diseased plant. Note bending downwards of petioles, distortion of growing point, abscission of leaves and streaks on stem.

Microscopic examination and agar-culture studies have revealed no organism present within the tissues of diseased organs. Juice inoculations from diseased plants to the foliage of healthy papaya plants, using carborundum as abrasive, have resulted in better than 75 per cent transmission. Symptoms produced exactly duplicate those seen in the field, and appear within 16 to 21 days after inoculation. When juice is rubbed on the stem of the papaya plant, stem streaking above and below the point of inoculation is the only symptom produced. Attempts to transmit the disease by grafting have been unsuccessful; diseased scions die before organic union takes place.

From these preliminary results it would appear that the disease in question is a virus. When a diseased papaya plant is decapitated or death of the growing point takes place naturally, new growth develops from the lower portions of the stem. It has been observed that the new shoots may all be healthy, or some be healthy and some diseased.



FIG. 3. Healthy shoots produced from a diseased plant. Note apex of plant reduced to a single, badly distorted leaf. Healthy tree of same age in background.

A papaya plant grown in an insect-proof cage in the greenhouse has been mechanically inoculated; after the disease developed, the plant was decapitated. Four shoots developed, all diseased. Following a second decapitation, two diseased shoots and one healthy shoot were produced. It has not yet been determined whether symptomless shoots generated by diseased plants contain a virus. Dr. F. G. Holdaway of the Hawaii Experiment Station is investigating the entomological aspects of the disease.

## Variation in Resistance to Brown Rot in Apricot Varieties and Seedling Progenies

By CLARON O. HESSE, *U. S. Department of Agriculture, Davis, Calif.*

**I**N certain years the climatic conditions during the blossoming period in the various stone fruit districts of California have been especially favorable to the development and spread of brown rot. Under such circumstances the efficient control of this disease is very difficult, and the regular spray program may prove wholly inadequate. The delay in the opening of the blossoms during rainy weather is probably an important factor because it allows a much longer period of infection at a time when the fungus is especially active. The spring of 1935 and that of 1938 were especially favorable to brown rot development throughout the fruit districts of central California at the time the apricots were in bloom. Under these circumstances, it was felt that

the several varieties growing in the variety block of the University of California Experiment Station at Davis could be rated as to their relative resistance to the disease. Such ratings were made by Mr. E. C. Hughes in 1935 and by the writer in 1938. In addition, a large block of apricot seedlings, which had never received a brown rot spray, was available for study, and readings were taken in 1938. The readings were made in the latter part of May, when foliage development was nearly completed.

Brown rot infection was estimated on a 0 to 5 basis, 0 indicating freedom from infection and 5 those most severely attacked by the disease. Ratings of 1 and 2 indicated increasing amounts of spur infection with but few infections running back into 2-year-old wood and with little or no apparent affect on foliage



FIG. 1. Typical example of apricot seedling (Wenatchee Moorpark x Tilton) severely infected by brown rot.

development. Ratings of 3 and 4 indicated severe spur infection and increasing infection of the older wood, large gum pockets often being found on the main secondaries in the more severe cases. The effect of such infection was apparent on the amount of foliage. Those rated as 5 were characterized by the loss of most of the spurs and much of the younger wood, severe gumming, and a much reduced leaf surface, the combined effects of which weakened the tree materially (Fig. 1).

Considerable variation in resistance to brown rot was shown by different varieties, but since the number of trees of each variety was small, and some measure of protection was afforded by the spray program, it was not feasible to rate the varieties. However, the readings for each variety checked closely in 1935 and 1938, never varying by more than one class. From these data several of the more important varieties may be ranked as follows: Susceptible varieties — Royal, St. Ambroise, Blenheim, Derby Royal, Newcastle and Oullins Early; moderately resistant — Tilton, Wenatchee Moorpark, Hemskirke, and Hersey Moorpark; and most resistant — Moorpark and Peach. This ranking agrees with general observations made in California on the more important commercial varieties in previous years.

In Table I the average ratings obtained in 1938 for the 1286 seedling trees (divided among 12 progenies) are shown, with their standard errors. In this seedling block 29 unsprayed trees of the Royal variety were located as check trees, and the average of these,  $3.55 \pm 0.1587$ , is also shown. The distribution of the seedlings and the Royal check trees into the six infection classes is also shown.

In Table II the results of the comparison between the Royal check trees and the various seedling progenies are shown, with the difference and the "t" values obtained. The "t" values indicate only significance or lack of significance from the Royal check trees. In all cases the progeny numbers were sufficient to make a "t" value of 1.96 significant.

It is realized that under the conditions of natural infection as obtained in this study there are probably many unknown factors which effect the results. For this reason the trends pointed out below are considered to be only suggestive. However, the degree of distribution of the disease was such that only one seedling tree out of all the seedlings and varieties was tentatively assigned a 0 rating. This would seem to indicate that partial escapes were relatively infrequent.

TABLE I—OCCURRENCE OF BROWN ROT IN APRICOT SEEDLING PROGENIES AFTER HEAVY, NATURAL INFECTION, SHOWING THE DISTRIBUTION AND MEAN RATING IN 1938

Cross	Number of Seedlings	Brown Rot Rating						Mean Rating $\pm$ E
		0	1	2	3	4	5	
Tilton $\times$ Moorpark.....	62	1	38	20	2	1	0	$1.42 \pm .0840$
St. Ambroise $\times$ Tilton.....	85	0	31	45	8	1	0	$1.75 \pm .0723$
St. Ambroise $\times$ Moorpark.....	88	0	32	36	15	3	2	$1.94 \pm .0995$
St. Ambroise $\times$ Royal.....	8	0	2	3	3	0	0	$2.12 \pm .2760$
Hemskirke $\times$ Tilton.....	19	0	4	8	6	1	0	$2.21 \pm .1909$
Blenheim $\times$ Self.....	15	0	1	6	6	2	0	$2.60 \pm .2066$
Hersey Moorpark $\times$ Royal.....	118	0	16	39	36	22	5	$2.67 \pm .0974$
Royal $\times$ Moorpark.....	198	0	11	28	84	72	3	$3.14 \pm .0623$
Wenatchee Moorpark $\times$ Tilton.....	29	0	2	4	12	7	4	$3.24 \pm .1990$
Royal $\times$ Hemskirke.....	84	0	2	10	35	34	3	$3.31 \pm .0890$
Royal $\times$ Newcastle.....	428	0	3	39	144	226	16	$3.50 \pm .0358$
Royal $\times$ Tilton.....	182	0	2	9	45	76	20	$3.68 \pm .0669$
Royal check trees.....	29	0	0	3	11	11	4	$3.55 \pm .1587$

The data presented in Table II show that St. Ambroise, Moorpark, and Tilton appeared to transmit resistance to brown rot to their progeny as compared to Royal, in the order named. Royal appeared to transmit susceptibility to a marked degree.

TABLE II—RESISTANCE TO BROWN ROT OF SEEDLING APRICOT PROGENIES COMPARED WITH THE ROYAL CHECK TREES IN 1938

Cross	Mean $\pm$ E	Difference	"t"
Significantly different from Royal check trees	3.55 $\pm$ .1587		
Tilton $\times$ Moorpark	1.42 $\pm$ .0840	-2.13	11.88
St. Ambroise $\times$ Tilton	1.75 $\pm$ .0723	-1.80	10.31
St. Ambroise $\times$ Moorpark	1.94 $\pm$ .0995	-1.61	8.96
St. Ambroise $\times$ Royal	2.12 $\pm$ .2760	-1.43	4.48
Hemskirke $\times$ Tilton	2.21 $\pm$ .1909	-1.34	5.40
Blenheim $\times$ Self	2.60 $\pm$ .2066	-0.95	3.65
Hersey Moorpark $\times$ Royal	2.67 $\pm$ .0974	-0.88	4.74
Royal $\times$ Moorpark	3.14 $\pm$ .0823	-0.41	2.41
Not significantly different from Royal check trees	3.55 $\pm$ .1587		
Wenatchee Moorpark $\times$ Tilton	3.24 $\pm$ .1909	-0.31	1.22
Royal $\times$ Hemskirke	3.31 $\pm$ .0890	-0.24	1.33
Royal $\times$ Newcastle	3.50 $\pm$ .0358	-0.05	0.33
Royal $\times$ Tilton	3.68 $\pm$ .0669	0.13	0.73

The St. Ambroise and Tilton varieties are of special interest in this regard. St. Ambroise itself is a rather susceptible variety, but in all cases its progeny were among the most resistant, regardless of the other parent. For example, when St. Ambroise was crossed with either a relatively resistant variety, such as Tilton; or with another susceptible variety, such as Royal, the progeny were more resistant than either parent. In the latter case the progeny were not as resistant as progenies of St. Ambroise crossed with the more resistant varieties.

Tilton, a rather resistant variety, is remarkable for the variation shown by its progeny, depending upon and accentuating the degree of resistance of the other parent. Thus, progenies of Tilton with Moorpark and St. Ambroise were very resistant, more so than either parent. However, when crossed with the susceptible variety Royal, the progeny showed no increase in resistance over Royal. With Hemskirke, a variety somewhat comparable to Tilton in resistance, the progeny were intermediate, and with Wenatchee Moorpark the progeny were less resistant than either parent. Moorpark showed this same tendency to a lesser degree.

Combinations of Hemskirke, Wenatchee Moorpark, and Newcastle with other varieties tended to be intermediate in resistance between the two parents. Where one of the parents was a resistant variety the progeny was usually significantly more resistant than the Royal check trees.

Under the conditions obtained in making these observations the 1 or 2 years results reported are not conclusive. Climatic conditions favoring such a general and severe occurrence of brown rot happen infrequently, so there is no assurance that these observations could be checked in the near future. In addition, the seedlings in these particular progenies are rapidly being eliminated, so that the results reported here are final so far as the present progeny is concerned. The data cannot be explained on any simple genetic basis, and the error of observation and classification is undoubtedly high. It was felt, however, that the results were of value in indicating the relative resistance to brown rot of the different varieties, and their general behaviour in transmitting resistance to brown rot.

# A Histological Study of the Developing Fruit of the Sour Cherry (*Prunus Cerasus* L.)

By H. B. TUKEY and J. ORAN YOUNG, *New York State Agricultural Experiment Station, Geneva, N. Y.*

## ABSTRACT

This material will be published in full in the *Botanical Gazette*.

**T**HIS paper pictures and discusses the gross development of the fruit of the sour cherry (*Prunus cerasus* L. var. Montmorency) from 18 days before full bloom to fruit ripening, and the histological changes in tissue during the Pre-bloom Stage, Stage I (rapid development for 20 days following full bloom), Stage II (retarded development for 16 days), and Stage III (rapid development for 21 days to fruit ripening).

Three principal tissues compose the ovary wall, namely, inner and outer epidermis, stony pericarp, and fleshy pericarp. The stony pericarp may be divided into an inner and an outer layer, the fleshy pericarp into an innermost layer of small, thin-walled parenchyma, a middle region of large thin-walled parenchyma, and an outer or hypodermal layer of collenchyma.

The fleshy pericarp and the stony pericarp are derived each from distinct groups of cells, which are early separated from each other by characteristic size, shape, and frequency and periodicity of division.

The inner layer of the stony pericarp is derived from the inner epidermis together with a few adjacent cells of the pericarp, and which form a band or "hoop" of transversely elongated cells bounding the inner ovary wall. The outer layer is derived from the pericarp, and the cells of which it is composed are elongated at right angles to those of the inner layer.

The cells of the stony pericarp increase in number during the Pre-bloom Stage and the first few days of Stage I, and enlarge during the latter part of Stage I. Cell walls become progressively thicker and by the end of the period the maximum number and size of cells is attained. During Stage II the walls thicken and harden greatly. During Stage III there is slight increase in hardness and brittleness.

The cells of the fleshy pericarp increase in number during the Pre-bloom Stage and the first half of Stage II. In the last half of Stage II they double in diameter. During Stage II there is slight enlargement. During Stage III the size of individual cells increases remarkably. Those of the hypodermal layer become enlarged in a tangential direction similar to the adjacent cells of the outer epidermis. Those in the outer portion of the fleshy pericarp become roundish oval, with the greatest diameter parallel to the periphery of the fruit; those next inward become roundish; those next, obovate in a radial direction; next, radially elongate; and innermost, decidedly radially elongate. At maturity the largest cells indicate an increase of 25 times in diameter from the size at full bloom.

The epidermal cells are elongated radially 18 days before full bloom. They increase rapidly in number during the Pre-bloom Stage and during the first half of Stage I, increase in size and wall thickness during the latter half of Stage I, change but little during Stage II, and greatly enlarge tangentially in Stage III.

The stomata are fully differentiated 18 days before full bloom. The guard cells increase in size as the fruit develops, but the increase is less than that of typical epidermal cells.

The similarity of other fruits and the mechanism of enlargement in Stage III are discussed.

# Reduction of Cracking in Sweet Cherries Following the Use of Calcium Sprays<sup>1</sup>

By LEIF VERNER, *University of Idaho, Moscow, Idaho*

IT is a matter of common observation among growers of sweet cherries that different varieties of this fruit exhibit marked differences in tendency to crack during periods of rain. Less generally recognized is the fact that individual fruits of the same variety may show equally great differences in this respect. In a variety such as Bing, for instance, which is generally regarded as highly susceptible to cracking, some of the fruits may crack during the first half hour of rain while other fruits, on the same tree and at a comparable stage of development, will remain sound after the rain has continued for 12 hours or longer.

It has been shown (3) that cherries differ in their susceptibility to cracking because of differences in rate of absorption of water (due largely to differences in permeability of the fruit skin), and because of unequal capacities for expansion of the peripheral tissues to accommodate the increased fruit volume that results when water is absorbed. Cherries with a rapid rate of absorption and a small capacity for expansion crack readily, while those with a slow rate of absorption and a large capacity for expansion tend to be immune to cracking. Differences in these respects occur not only among the fruits of different varieties but also among individual specimens of the same variety.

It is reasonable to assume that both the degree of permeability of the fruit skin and the plasticity of the peripheral tissues may be subject to modification. Any treatment that will decrease the rate of absorption of water, and any treatment that will increase the capacity of the fruit tissues to stretch without rupturing, should reduce the general level of susceptibility to cracking. Evidence of some such modification is offered in the recent report of Foster (1) regarding observations in British Columbia in 1936, when cracking of cherries was unusually severe in that province. According to this report, a grower on Vancouver Island who had sprayed his cherries with a 2-3-40 Bordeaux mixture for control of brown rot observed a decreased tendency towards cracking following this treatment. Subsequent laboratory tests conducted at Saanichton, British Columbia, gave further evidence that Bordeaux sprays tend to reduce cracking, and this effect Foster (2) has suggested might be attributable to a decreased rate of absorption of water due to altered skin permeability.

The present paper deals briefly with the results of experiments in the use of Bordeaux mixture and certain other sprays for the control of cracking of cherries at Lewiston, Idaho, in 1938.

## METHODS

Treatments consisted of spraying representative branches with different strengths of Bordeaux mixture and with water solutions of

<sup>1</sup>Published with the approval of the Director of the Idaho Agricultural Experiment Station as Research Paper No. 176.



calcium hydroxide and calcium acetate. Degree of susceptibility to cracking was determined in the laboratory by immersion in water of freshly picked fruit according to the method outlined by Verner and Blodgett (4). Cherries from sprayed and from adjacent, untreated branches were tested for susceptibility to cracking at intervals of 1 to 19 days after spraying. These observations in the laboratory were supplemented by orchard counts of cracked cherries on treated and untreated branches following periods of rain.

Samples of freshly picked, unsprayed fruit were treated in the laboratory by immersion for periods of 15 to 30 minutes in water solutions of different forms of calcium. These treatments were followed immediately by the water immersion test for susceptibility to cracking.

To furnish some measure of the maturity of different samples of fruit the approximate sugar concentration of the juice was determined by use of a Zeiss refractometer, and the water displacement of 50 cherries of each sample was used as a measure of fruit size. Since the results of these tests show that there were no significant differences in maturity between any of the treated samples and their respective controls, maturity may be disregarded as a factor in the observed differences in cracking.

## RESULTS AND DISCUSSION

The results of cracking tests following various treatments are given in Table I. It is noteworthy that calcium was used in some form in all of these treatments, and that all treatments were followed by a rather remarkable decrease in susceptibility of the fruit to cracking. This was especially noticeable during the first 2-hour and 4-hour periods of immersion in water, after which many of the treated samples closely approached the checks in per cent of cracked fruit. Averaging the results of all treatments, we find that in the first 2 hours of immersion those cherries that had been subjected to a spray containing calcium, and those that had been immersed in solutions of calcium hydroxide, had an average of 11.8 per cent of cracked fruit, while the untreated control samples averaged 38.5 per cent. At the end of 4 hours the corresponding figures were, respectively, 51.5 per cent and 74.5 per cent.

*Cherries growing under natural conditions in the orchard require more than twice as long to reach a given severity of cracking during rain as is required by picked fruit immersed in water. Therefore, the 2-hour and 4-hour periods of immersion represented in Table I may be considered equivalent, respectively, to over 4 hours and over 8 hours of rain under field conditions. Since many, if not most periods of rainfall at Lewiston during the cherry season do not exceed 8 hours, it is evident that these calcium treatments afforded a considerable protection against cracking. Their practical value under field conditions was demonstrated on several occasions. Thus, on June 25, following a 5 hour period of rain, an orchard count of Bing cherries sprayed 19 days previously with a 4-6-50 Bordeaux mixture showed that only 13 per cent of the treated fruits were cracked, in contrast to 32 per cent on adjacent, unsprayed branches.*

TABLE I—EFFECTS OF CALCIUM TREATMENTS OF SWEET CHERRIES ON RATE OF CRACKING DURING IMMERSION IN WATER

Date (June)	Variety	Treatment	Cherries Cracked at 2-Hour Intervals During Immersion in Water. (50 Cherries per Sample) (Per Cent)				
			2 Hour	4 Hour	6 Hour	8 Hour	10 Hour
14	Bing	Sprayed June 6 with 4-6-50 Bordeaux Check—no treatment . . . . .	2 10	26 40	50 60	68 82	74 86
20	Lambert	Sprayed June 14 with 2-3-40 Bordeaux Check—no treatment . . . . .	0 24	18 50	56 86	78 90	92 100
20	Bmg	Sprayed June 14 with 2-3-40 Bordeaux 15 minutes in saturated calcium hydroxide solution before immersion in water . . . . . Check—no treatment . . . . .	22 14 60	72 62 96	100 82 100	100 98 100	100 98 100
21	Bing	Sprayed June 14 with 4-4-50 Bordeaux 30 minutes in saturated calcium hydroxide solution before immersion in water . . . . . Check—no treatment . . . . .	22 10 46	62 42 80	84 80 90	92 84 96	96 92 98
23	Lambert	30 minutes in saturated calcium hydroxide solution before immersion in water . . . . . Check—no treatment . . . . .	0 18	8 60	72 82	96 90	98 92
24	Lambert	Sprayed June 21 with 6 lbs. calcium hydroxide to 50 gals. water . . . . . Check—no treatment . . . . .	20 42	78 86	100 98	100 100	100 100
25	Bing	Sprayed June 6 with 4-6-50 Bordeaux Check—no treatment . . . . .	30 56	78 82	96 98	98 100	98 100
26	Lambert	30 minutes in saturated calcium hydroxide solution before immersion in water . . . . . Check—no treatment . . . . .	2 26	56 84	84 96	98 100	98 100
29	Lambert	Sprayed June 28 with saturated calcium hydroxide solution . . . . . Check—no treatment . . . . .	8 36	64 66	94 92	96 94	98 96

Sprays in which only hydrated lime was used, as on June 24, were just as effective as those in which hydrated lime and copper sulphate were used together. A spray consisting of a concentrated solution of calcium hydroxide in water reduced cracking as much as did sprays containing a considerable excess of calcium hydroxide in suspension.

We may conclude from these observations that calcium is the effective constituent of Bordeaux mixture in its action on cracking, and that probably only the calcium in solution is effective. Results of treatments applied in the laboratory, using various forms and concentrations of calcium, support these conclusions.

Apparently a small fraction of the amount of lime ordinarily contained in a Bordeaux spray suffices to reduce cracking materially. A concentrated solution of calcium hydroxide, such as used in spraying on June 29 and for treatment by immersion on several occasions, contains only .089 parts, by weight, of calcium in 100 parts of water. A 4-6-50 Bordeaux mixture made with hydrated lime contains approximately 13.7 times this amount of calcium per unit weight of water; but the greater part of this lime is merely in suspension and, therefore, probably without influence on cracking.

Due to greater solubility, calcium in other forms may prove more effective than calcium hydroxide. The acetate, a concentrated solution of which contains over 100 times as much calcium per unit weight of solvent as is contained in a concentrated solution of the hydroxide, has proved especially promising.

The nature of the action of calcium in reducing susceptibility of cherries to cracking has not been determined, but it is evident that this action depends upon direct contact of the spray with the fruit, since cherries that were enclosed in paper bags at the time of spraying were unaffected, even though the foliage all about them was sprayed heavily. Results following various laboratory treatments also give evidence of a direct effect of calcium on the fruit itself. Whether or not this effect involves a change in permeability of the outer cell membranes such as would lower the rate of absorption of water has not yet been determined.

Although they offer considerable promise as means of reducing cracking, none of the treatments described can yet be recommended for other than experimental purposes. All the sprays employed left visible residues on the fruit. These residues were reduced or entirely removed by washing the fruit in a 1 per cent solution of acetic acid, but such an operation would add materially to the cost of handling the crop and, in commercial practice, it no doubt would result in damage to some of the fruit. Calcium acetate left an inconspicuous residue but it impaired the natural luster of the cherries, giving them an aged appearance. Sprays of calcium hydroxide containing only such an amount as would go into solution left much less residue than sprays containing additional quantities of this material in suspension, as in Bordeaux mixtures. This problem of residues might be largely circumvented by applying the sprays very early in the season when the fruit still is quite small. Subsequent increase in surface area of the fruit as it grows, and the effects of weathering, would materially reduce the concentration of the residue. There is evidence that such early applications remain effective for several weeks.

### SUMMARY

Sprays of Bordeaux mixture greatly reduced the susceptibility of sweet cherries to cracking, as determined both under field conditions and by water immersion tests in the laboratory. The dissolved fraction of calcium was shown to be the effective constituent of the spray in this action. Both spray and immersion treatments of cherries with different forms of calcium in water solution reduced cracking materially. Conspicuous residues left by calcium sprays are an objectionable feature in the practical application of these treatments.

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# First Progress Report on Prune Drouth Spot

By A. B. BURRELL and RALPH M. HEINICKE, *Cornell University, Ithaca, N. Y.*

SEVERAL imperfectly understood abnormalities of fruit and foliage may be found in the commercial prune orchards of New York State. Among these, the so-called drouth spot merits special consideration since it affects a majority of the fruits in dozens of plantings in certain years. It causes great concern in the Lake Ontario fruit belt where sizeable prune blocks are numerous, but also occurs in the Hudson River Valley. It is not confined to any one soil type.

Similar symptoms have been reported from widely scattered regions. Dippenaar (1) named a comparable trouble in South Africa "Kelsey Spot" for the variety on which it is most prevalent. He used the name "drouth spot" for lesions originating earlier in the summer, and "sun spot" for lesions with somewhat different characteristics consistently located on the sunny side of the fruits. Since he was able to produce internal lesions by raising the temperature of plums in an oven, he concluded that the name "heat spot" would cover all three. Proebsting (4) confirmed Dippenaar's claim that lesions could be produced by holding plums in an oven at a rather high temperature (107 degrees for 15 to 72 hours) and felt that a heat wave would explain an outbreak of Kelsey spot of plums shortly before picking time in California in 1935. In a later paper, Dippenaar (2) supported his view that high fruit temperature is the chief causal factor, and observed in addition that perhaps the trouble was slightly alleviated by the use of a fertilizer mixture of superphosphate, potash and nitrogen. McLarty and Wilcox (3) in a purely incidental way, mention prune drouth spot among the diseases preventable by the use of boron. Last summer Dr. R. E. Fitzpatrick of the Dominion Laboratory of Plant Pathology, Summerland, British Columbia, showed me drouth spot (or gum spot as they sometimes call it) on prunes and several other plum varieties in that Province. There was no obvious difference in symptoms from what we have in New York. Exchange of specimens with Dr. E. C. Blodgett of the Idaho Agricultural Experiment Station revealed no obvious difference in symptoms between Idaho and New York. It is apparent from conversations with investigators in other northwestern states that a similar drouth spot of prune is known in much of that area.

Extension workers and growers in New York State usually consider prune drouth spot due to water deficiency in the fruits brought about by such factors as high temperature, drying winds, and dry soil. A very heavy foliage is thought to increase the likelihood of an outbreak by increasing the demand for water.

## SYMPTOMS IN NEW YORK STATE

Anywhere on the green surface of partly-grown prunes, roundish or irregular areas  $\frac{1}{8}$  to  $\frac{1}{4}$  inch across, turn purplish, then brownish. Beneath each spot may be found, browned necrotic tissue and more or

less of a hollow partly filled with gum. The epidermis cracks above many of these pockets, permitting the extrusion of gum. Toward autumn, the lesions may become inconspicuous due to normal coloring of the fruit and weathering off of much of the gum. The blemished fruit may then be marketable, but the spot furnishes an excellent infection court for micro-organisms. Brown rot takes a heavy toll when a rainy period follows an outbreak of drouth spot.

Several foliage symptoms may be associated with prune drouth spot, but from evidence thus far obtained, they are tentatively considered of separate origin.

### GENERAL PLAN OF ORCHARD PLOTS

While other approaches have not been overlooked, this first report deals mainly with the possible relation of mineral nutrition to the occurrence of prune drouth spot. Many diseases now known to be controllable through supplying the proper minerals were first regarded as due solely to abnormalities in temperature or water supply.

Two orchards in Niagara and one in Wayne County of the Lake Ontario fruit belt were chosen for plot tests because of the uniformity of their trees and their past drouth spot records. In 1937, all three had drouth spot on every tree, and the distribution seemed fairly even over the areas chosen for the present experiments. The same materials and approximately the same layout were used in each orchard. Six trees in a row constitute a plot. Alternate rows are untreated, each treated tree thus being between two untreated checks.

On May 1, 1938, each of the chemicals used except potassium sulfate and superphosphate was broadcast in a circle well inside the "drip" of the branches. The potassium sulfate and superphosphate (20 per cent) were placed in eight holes about 10 inches in diameter and 8 inches deep evenly spaced around each tree in the plot, about 4 feet from the trunk. These materials were thus placed in contact with the roots. The others were left on the surface.

### RESULTS

In 1938, neither Niagara County orchard developed more than a trace of drouth spot. The present report is based on data taken in the Wayne County orchard where there was a moderate amount of this disease.

The trees in this block are about 18 years old, 10 feet high, and have a spread of about 12 feet. They are in relatively low vigor, perhaps due to inadequate subsoil drainage. In advance of the differential treatments, the grower had given each tree about 3 pounds of sodium nitrate.

Fifty random fruits distributed around the tree constituted a sample. First, a sample was examined from the three east trees in each plot. Where the data thus obtained, suggested a possible influence of treatment the other three trees in certain plots were examined. The more detailed original data were condensed to the form shown in Fig. 1, which is a map giving the percentage of fruits with drouth spot on individual trees.

It is apparent from Fig. 1 that no treatment has yet brought about anything approaching complete control. Such differences as exist may be mere variation independent of treatment. Among the 16 plots, number 5, which received potassium sulfate and superphosphate, has the least drouth spot relative to the amount on adjacent checks. Each of the six trees in this row shows less drouth spot than does the corresponding check tree north or south of it. The sixth tree, which had treatment, also shows less than the three nearest check trees west of the plots. No other treatment is consistently superior to the adjacent checks.

		Row			Treatment	Percent drouth spot
		80	74	78	I Bone	$\frac{1}{2}$
		80	98	54	I None	
		78	46	62	II Potassium Sulfate	$\frac{1}{4}$
88	100 48 90	74	86	57	II None	
80	42 30 48	26	16	24	I Sulfate Plus Superphosphate	5
54	46 57 57	70	50	20	II None	10
		74	66	76	III Copper Sulfate	2
		46	76	78	III None	
		40	52	57	IX Zinc Sulfate	2
		36	80	36	I None	
					None	

## DISCUSSION

The data are far too meager to prove that potash and superphosphate are beneficial. Perhaps more nearly conclusive is the failure of borax to benefit the trees. Soil applications of this element so consistently have controlled boron-deficiency symptoms that the present apparently discouragingly significant treatment may not have been one of the best methods of supplying boron.

Plans for the future include continuation of the plots in these three orchards for several years. They will be supplemented by additional replications and by plots receiving other chemicals.

## CONCLUSION

As one phase of a study of the so-called drouth spot of prune, mineral nutrient plots were laid out in three western New York State prune orchards. The materials applied were borax, ammonium sulfate, potassium sulfate and superphosphate, copper sulfate, zinc sulfate, manganese sulfate, and ferrous sulfate. Only one of the three orchards had an appreciable amount of drouth spot in 1938. In it, the only plot with consistently less drouth spot than adjacent checks was the one receiving potassium sulfate and superphosphate. Continuation and augmentation of the work ultimately may show whether this difference was due to treatment or accident.

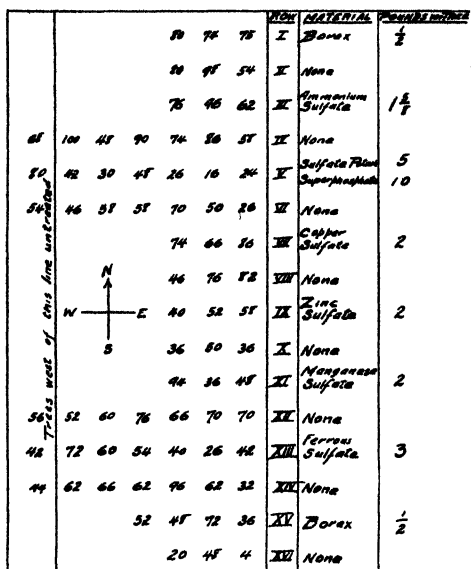


FIG. 1. Map showing percentage of fruits with drouth spot on individual prune trees differentially fertilized.

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# Apple Breeding: Inheritance and Statistical Studies on the Fruits of Crossbred Seedlings with Antonovka Parentage<sup>1</sup>

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THIS report is based on data collected by the Pomology Subsection of the Iowa Agricultural Experiment Station, Ames, Iowa. The purpose was to study the seedling fruits produced by eight progenies of Antonovka to determine: (a) whether the variations and differences between progenies were statistically significant; (b) the breeding value of the various parental varieties involved in these crosses; and, (c) to examine the genetic inheritance of the different fruit characteristics.

The trees of the progenies of Antonovka were outstanding in vigor and hardiness, and the fruits of these progenies presented an opportunity to study the variations in genetic make-up of six parent varieties used in making the crosses. In this discussion, only size, color, quality, and season will be considered.

The variety Antonovka is an apple of Russian origin. It is one of the hardest and most productive of the large fruited varieties, is a diploid and crosses readily with other diploids. The fruit is above medium to large in size, roundish inclined to conic, the color is a pale greenish yellow sometimes with a slight blush, the flesh is pale yellow, firm, coarse, medium tender, juicy, sprightly sub-acid, fair quality, and the season, September.

## METHODS

The data in this paper were collected from fruit descriptions made during the years 1932 to 1937, inclusive. The fruit description sheets were standardized to secure uniformity of record and to facilitate summation.

The history of the seedlings concerned in this investigation is as follows: The entire group of seedlings were planted the same year, 1924, thus reducing variation due to time of planting. Trees of the same cross were set out in one or more rows, thus practically eliminating position effect, for experiments have shown that in a fairly uniform soil that the variations encountered in a single row tend to cancel one another. The trees were all planted the same distance apart, and all received the same cultural treatments as far as spraying, pruning, and fertilizing were concerned.

It is commonly known that the apple varieties vary from year to year in the expression of their fruit characteristics. Wilcox and Angelo (1) found that the environment is capable of changing a solid red apple to a highly striped apple from one year to the next, but is not powerful enough to change a solid red apple to a lightly striped apple. Lantz has

<sup>1</sup>Journal Paper No. J-615 of the Iowa Agricultural Experiment Station, Ames, Iowa, Project No. 284



made similar observations on other characteristics of the apple, and it appears that year to year variations are not great enough to seriously change the results. All the above facts were taken into consideration in choosing a suitable method of analyzing these data. The method finally selected was a modification of group comparison which involved the standard error of the mean difference. It was selected partly because it was readily adaptable to the data and partly because it took into account all variance not due to inheritance. The standard error of the mean difference was computed by the formula,

$\sqrt{(S.E. \bar{a})^2 + (S.E. \bar{b})^2}$ . Wherever the difference of the means in question between two progenies was at least twice the *standard error of the mean difference*, the difference was considered genetically significant.

This method of comparing means made it necessary to assign index numbers to each of the characteristics under consideration, and from these the mean, standard deviation, and standard error were computed. Table I concerning the fruit size of the seedlings from the Antonovka x Delicious cross will illustrate the preliminary work involved.

TABLE I—INDIVIDUAL SIZE RECORD ANTONOVKA x DELICIOUS (N-195)

Fruit		I Index Number	F Frequency	I (F) Product
Size	Groups (10 Units = $\frac{1}{2}$ inch)			
Large . . . . .	3 to $3\frac{1}{2}$	5	16	80
Above medium . . . . .	$2\frac{3}{4}$ to 3	4	73	292
Medium . . . . .	$2\frac{1}{2}$ to $2\frac{3}{4}$	3	59	177
Below medium . . . . .	$2\frac{1}{4}$ to $2\frac{1}{2}$	2	37	74
Small . . . . .	2 to $2\frac{1}{4}$	1	10	10
Total . . . . .		—	195	635

$$\text{Mean} = \frac{S(I \cdot F)}{n}$$

$$\text{Index mean} = 3.246 = 2.55\text{-inch apple}$$

$$\text{Sum products} = S I \cdot (I \cdot F)$$

$$\text{Sum product} = 2257$$

$$\text{Square products} = \frac{(I \cdot F)^2}{n}$$

$$\text{Square product} = 2054.82$$

$$\text{Sum squares} = (\text{sum prod.}) / (\text{Sq. prod.})$$

$$\text{Sum squares} = 202.18$$

$$\text{Standard deviation: } s = \sqrt{\frac{S x^2}{n-1}}$$

$$s = \pm 1.0208$$

$$\text{Where } S x^2 = \text{Sum squares}$$

$$S.E. = \pm .0731$$

$$\text{Standard error} = s\sqrt{n}$$

#### STUDIES ON SEEDLING FRUITS OF ANTONOVKA PARENTAGE

*Size*.—Figs. 1 and 2 show the distribution of fruit size of the individual Antonovka crosses. The cross Antonovka x Delicious, while it did not produce the greatest percentage of "large" apples, threw over 75 per cent of its  $F_1$  progeny into the classes, medium and above. At the other end of the scale only 47.7 per cent of the progeny of Antonovka x Ashton fell within the medium to above group. The marked

variability between the two crosses indicates, insofar as these progenies of Antonovka are concerned, that Delicious transmitted those factors that produce large fruit size to a greater extent than did any of the other varieties. Where fruit size was concerned Delicious proved to be a better parent than any of the other five varieties with which Antonovka was crossed.

In this connection it is important to note that the distributions for fruit size of the Antonovka x Jonathan and the Antonovka x King David crosses are closely parallel, indicating that Jonathan and King David carry similar factors for fruit size.

Irregular segregations in progenies of different crosses supports the hypothesis held by the majority of fruit breeders that size is governed by more than one factor, and that parent varieties often differ considerably in their genetic make-up. It is also quite probable, although adequate data are lacking, that inheritance of size is on a quantitative basis. Mean fruit size among the seedlings of the Antonovka and Grimes reciprocal crosses was found to be significantly different. When Antonovka was the female parent, the mean size of the progeny was over  $2\frac{1}{2}$  inches but when Grimes was the female parent, the mean size of the fruit was slightly over  $2\frac{1}{4}$  inches.

**Color:**—The color analysis of the Antonovka crosses was limited to a few, although important points. Color groups were chosen as follows: red, striped, blush, and

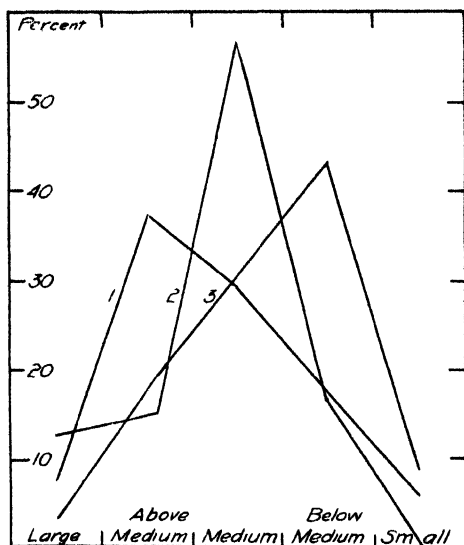


FIG. 1. Distribution of fruit sizes produced by: 1. Antonovka x Delicious—(190 seedlings); 2. Antonovka x Grimes—(59 seedlings); and 3. Antonovka x Ashton—(107 seedlings).

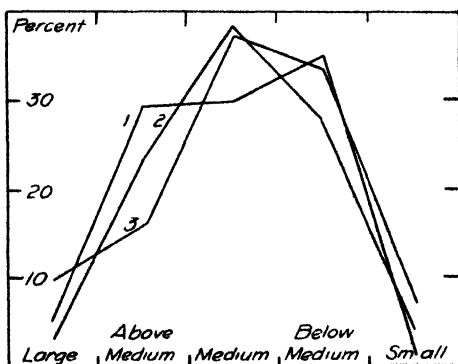


FIG. 2. Distribution of fruit sizes produced by: 1. Antonovka x Black Oxford—(41 seedlings); 2. Antonovka x Jonathan—(117 seedlings); and 3. Antonovka x King David—(65 seedlings).

no red. Frequency distributions were calculated in percentages for each of the Antonovka crosses and the results are listed in Table II.

TABLE II—FRUIT COLOR DISTRIBUTION OF PROGENIES OF ANTONOVKA

Cross	Number	Percentage			
		Red	Striped	Bluish	Yellow
Antonovka × Ashton . . . . .	107	16.8	83.2	0.0	0.0
Antonovka × Black Oxford . . . . .	41	22.0	78.0	0.0	0.0
Antonovka × Delicious . . . . .	195	3.0	44.2	9.5	43.1
Antonovka × Jonathan . . . . .	116	23.0	74.6	0.9	1.7
Antonovka × King David . . . . .	65	32.3	66.2	1.5	0.0
Antonovka × Grimes . . . . .	59	1.7	3.4	13.5	81.4

By classifying the seedlings into two categories, red and no red, several observations were at once apparent. In the four Antonovka crosses which involved red varieties, Ashton, Black Oxford, Jonathan and King David, no semblance of a genetic ratio appeared, and the results indicate that the varieties, Jonathan, King David, Black Oxford, and Ashton carry homozygous factors for red color. The cross Antonovka × Grimes and reciprocal indicated segregation on a three factor basis, but when fitted to a Chi Square test for goodness of fit it gave a probability of correctness of only 10 per cent which is scarcely high enough to warrant the above assumption. The color segregations of the seedling fruits of the cross Antonovka × Delicious suggested that a single factor difference could be responsible for the 1:1 ratio of red to yellow, and when the Chi Square test of goodness of fit was applied, the probability of correctness of this assumption was over 90 per cent. The behavior of Delicious indicates that this variety is heterozygous for red and yellow.

A study of fruit color in these crosses, and others as well, show that red coloring is practically homozygous in Jonathan, King David, Black Oxford, and Ashton. Yellow acts as a recessive to red. Antonovka carries yellow in a nearly homozygous condition.

*Quality*.—Quality in apples is based upon the flesh characteristics—firmness, texture, grain, flavor, and juice. In these studies the seedling fruits were placed in four categories, *i.e.*, very good, good, fair, and poor. In evaluating seedling apple fruits as to quality, the standard was based on a horticultural conception of those flesh characteristics which determine the quality of each seedling. Therefore, seedling fruits which were rated as “very good” in quality were similar to standard named varieties which are recognized as “very good” in quality.

Antonovka × King David and Antonovka × Grimes produced seedlings which rated good and very good, as also did Antonovka × Delicious and Antonovka × Jonathan. The seedlings of Black Oxford and Ashton were unusually poor in quality being significantly inferior to the other four varieties.

It is interesting to note, however, on a 4,3,2, and 1 basis where four equals a very good quality of apple, that the average of the Antonovka progenies was low in point of quality, in fact the average quality of the combined crosses was from a horticultural evaluation “poor”. In these

progenies it was apparent that poor quality was partially dominant to good quality.

King David, Grimes, Delicious, and Jonathan transmitted approximately the same factors for average quality, while Black Oxford and Ashton transmit fruits of a quality below average. The lack of distinct groups of segregates suggests that quality is controlled by several genes.

*Season*.—Antonovka, a fall apple, when crossed with winter apples, gave progenies whose means fell into an intermediate season of maturity. As was true with fruit size and color, the ripening dates of the Antonovka x Jonathan and the Antonovka x King David crosses were very nearly parallel, indicating a close relationship between these varieties. Of the six parent varieties, only Black Oxford gave indication that it carried factors for late maturity. The variations encountered in time of fruit maturity of the various crosses is clearly shown by the following comparison: 65.8 per cent of the seedling fruits of the Antonovka x Black Oxford cross "ripened" after January, while in contrast, 82 per cent of the fruits of the Antonovka x Ashton cross were mature by December.

It is evident that the variations in season are controlled on a multiple factor basis, and that these controlling factors are present in all of the varieties in an extremely heterozygous condition. No degree of dominance of lateness over earliness could be detected, although Black Oxford gave a slight indication that it possessed partially dominant genes for late maturity.

#### PRACTICAL RESULTS

The seedling fruits produced by all of the Antonovka crosses were generally deficient in desirable red color and in quality. However, these studies have shown that the seedling fruits produced by the crosses of Jonathan, King David, and Delicious were superior in all respects to those produced by the other parent varieties. A number of fruits were found which were much superior to Antonovka. Nine seedlings were selected for second test.

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# Incompatibility of Early McIntosh and Cortland Apples<sup>1</sup>

By WALTER WEEKS and L. P. LATIMER, *University of New Hampshire, Durham, N. H.*

THE comparative effectiveness of pollen varieties on McIntosh and some of its seedlings in New Hampshire has been reported previously (4). Table I shows the results including information obtained since publication of that paper. The result for Early McIntosh as female parent in 1936-37 has been added. Cross-compatibility undoubtedly exists between McIntosh and its seedlings Melba, Milton, Cortland, Macoun and Early McIntosh. The same relation exists between each of these seedlings with the exception of the cross Cortland and Early McIntosh, where cross-incompatibility seems to exist.

TABLE I—COMPARATIVE EFFECTIVENESS OF POLLEN VARIETIES ON MCINTOSH AND SOME OF ITS SEEDLINGS, 1934-37 (PER CENT OF BLOSSOMING SPURS SETTING AND MATURING FRUIT)\*

Pollen Variety	Variety Pollinated						Mean ( $\sigma^7$ )
	McIntosh	Melba	Milton	Cortland	Macoun	Early† McIntosh	
McIntosh . . . . .	2	51	76	59	88	72	69.2
Melba . . . . .	64	22	65	50	82	100	72.2
Milton . . . . .	69	70	0.5	62	84	74	71.8
Cortland . . . . .	66	71	66	3	75	3	69.5
Macoun . . . . .	—	81	67	60	1	74	70.5
Early McIntosh . . . . .	60	70	60	5	71	1	65.3
Starking . . . . .	76	82	75	66	72	—	74.2
King . . . . .	3	0	6	6	0	0	2.5
Mean $\sigma^7$ . . . . .	67.0	70.8	68.2	59.4	78.7	80.0	—

\*Means are for results in compatible crosses only.

†The results for Early McIntosh as female parent are for 1936-7 only.

On the average there is little difference between the effectiveness of pollen parents of the McIntosh group of apples when used with the other compatible McIntosh-type varieties tested. In all these cases the amount of fruit developing to maturity is more than sufficient for a satisfactory commercial crop.

King was included as a pollen parent to compare the effect of a triploid variety as pollinizer. Stamens were removed from blossoms pollinated by King to eliminate the possible effects of self-pollination. King was found to be unsatisfactory when used as a pollinizer for all McIntosh family apples used in the test.

Attention is called primarily to the low set of fruit obtained when Early McIntosh was pollinated by Cortland and *vice versa*. These results are practically the same as those recorded for self-pollination of the same varieties or for their pollination by the triploid variety, King.

Inasmuch as cross-incompatibility between diploid apple varieties is of uncommon occurrence (3), the following investigation was undertaken for the purpose of determining the cause of cross-incompatibility between Cortland and Early McIntosh (5).

Trees of McIntosh, Cortland and Early McIntosh were enclosed in cheesecloth tents or cages just prior to bloom in order to exclude

<sup>1</sup>Scientific Contribution No. 67, University of New Hampshire.

insects. Blossoms, subsequently to be hand-pollinated, were emasculated by removing the stamens with tweezers before dehiscence had occurred. Self- and cross-pollination was performed with these varieties a day or two later. Ideal weather conditions prevailed (Table II). Samples of the pollen used in the pollination tests showed the following percentage germination after 20 hours in cane sugar solution at room temperature: McIntosh 77 per cent, Early McIntosh 70 per cent, and Cortland 57 per cent. Random samples of pollinated blossoms were then obtained 12, 24, 48 and 72 hours, and 7 and 11 days respectively after pollination, and killed in Navaschins fixing solution. Gases were removed from the collected specimens with a vacuum pump to hasten the penetration of the fixing solution. This material was later imbedded in paraffin, sectioned, stained with acid fuchsin and light green, and mounted in balsam.

TABLE II—WEATHER RECORDS DURING EMASCULATION, POLLINATION, AND COLLECTION OF SAMPLES (1937)

Date	Temperature (Degrees F)		Precipitation (Inches)
	Maximum	Minimum	
May 20 .....	58	47	.91
21 .....	76	42	—
22 .....	71	47	—
23 .....	63	49	—
24 .....	75	51	.46
25 .....	78	52	—
26 .....	74	47	—
27 .....	66	52	.34
28 .....	71	52	—
29 .....	79	48	—
30 .....	90	56	—
31 .....	97	58	—
June 1 .....	97	60	—
2 .....	79	60	—
3 .....	67	41	1.22
4 .....	76	51	—

Table III summarizes the observations. When Cortland was pollinated by Early McIntosh and *vice versa*, no pollen tube progressed more than one-quarter the distance down the style. Pollen tube growth ceased within 24 hours of pollination and by 48 hours the tube tips had become swollen or club shaped. No change could be noted in the condition of the embryo sac until after 72 hours. Apparently, the adverse effects were effective slightly sooner when Early McIntosh was pollinated by Cortland than when Cortland was pollinated by Early McIntosh. This is indicated by the fact that embryo sac disintegration was slightly in advance of the same condition in the Cortland x Early McIntosh pollination. No embryo formation could be detected in the material under examination.

When Early McIntosh was self-pollinated, pollen tubes progressed slightly farther down the style than with the above, reaching ultimately one-third the distance down the style. Embryo sac disintegration was somewhat retarded in self-pollinated Early McIntosh blossoms compared with the previously mentioned cases. Pollen tubes showed tip-swelling within 24 hours, no adverse effects being observed in the embryo sac, however, in material collected even 7 days after pollination. Disintegration then took place rapidly so that on the eleventh day the embryo-sac was completely disintegrated.

As a check, blossoms of the compatible crosses, McIntosh pollinated

TABLE III—PROGRESS OF POLLEN TUBES DOWN STYLES

Time after Pollination	24 Hours	48 Hours	72 Hours	7 Days	11 Days
Early McIntosh × Cortland					
Distance down style..	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$		
Tube tips .....	O.K.	Swollen	club		
Embryo Sac .....	O.K.	O.K.	O.K.	Egg disintegrating	Egg and polar nuclei disintegrated
Cortland × Early McIntosh					
Distance down style..	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$		
Tube tips .....	O.K.	Swollen	Swollen	Disintegrating	Egg disintegrated—polar nuclei disintegrating
Embryo Sac .....	O.K.	O.K.	O.K.		
McIntosh × Early McIntosh					
Cortland × McIntosh					
Distance down style..	$\frac{1}{4}$ – $\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$		
Tube tips .....	O.K.	O.K.	O.K.		
Embryo Sac .....	O.K.	O.K.	O.K.	2 to 3 celled embryos	Several celled embryos
Early McIntosh × Self..					
Distance down style..	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$		
Tube tips .....	O.K.	Swollen	Swollen		
Embryo Sac .....	O.K.	O.K.	O.K.	O.K.	Complete disintegration

by Early McIntosh and Cortland by McIntosh, were examined. Little difference could be detected between these crosses and the incompatible and self-pollinations with relation to pollen tube development up to 24 hours. After this period pollen tube growth progressed steadily until the ovary was attained. In 7 days many 2- to 4-celled embryos were observable. By 11 days, 4- to 8-celled embryos were present.

Bryant (1) noted that fertilization and normal development of the embryo sometimes occurred when McIntosh was either self-pollinated or pollinated by the triploid varieties Baldwin and Gravenstein. Such development was retarded, however, compared with the normal development obtained in compatible crosses and, according to him, failure to set fruit was caused by embryo abortion.

In the present work self-pollination apparently caused some stimulation and retarded embryo sac disintegration. On the other hand, pollination of Cortland by Early McIntosh or of Early McIntosh by Cortland did not produce this stimulating effect. This was indicated by the earlier disintegration of the embryo sac. Furthermore, failure to set fruit in this case resulted from arrested pollen tube growth and consequent failure of fertilization. Presumably Cortland and Early McIntosh carry the same incompatibility factors, which would explain the cause for cessation of pollen tube growth in 24 hours. This is in accord with the explanation offered by Crane and Lawrence (2) of incompatibility found in diploid fruits.

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## Some Plant Characteristics of the Progeny of *Prunus Persica* and *Prunus Kansuensis* Crosses

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IN 1925, an interspecific cross between *Prunus persica* Batsch. and *Amygdalus kansuensis* (Rehd.) Skeels—*P. kansuensis* Rehd. was made at New Brunswick, New Jersey. The J. H. Hale, a representative variety of the species *P. persica*, was used as the female parent. Descriptions of the species and of this well known variety are given by Hedrick (1). The pollen parents, two types of *P. kansuensis*, were introduced by the Division of Plant Exploration and Introduction in 1914 and 1915 under the introduction numbers P.I. 39428 and P.I. 40001. The following field notes were made by F. N. Meyer, plant explorer who collected the pits from which have come these types of *P. kansuensis*:

"P.I. 39428. *Amygdalus kansuensis*—peach, received in Washington, November, 1914 (No. 2123a, Sianfu, Shensi, China, August 21 to 26, 1914). Stones of the real wild peach, growing in the mountains one day's journey south of Sianfu. The fruits are small, hard, and sourish, but there is considerable variation in them as regards size and taste. They are apparently all freestones, and while some have red flesh near the stone, others are white throughout. The Chinese eat these fruits out of hand, but they do not appeal to the white races, although they might be utilized when preserved, as they possess the real peach flavor. Local name *Ying tao*, meaning "Cherry peach".

"P.I. 40001. *Amygdalus kansuensis*—peach, received in Washington, March 2, 1915 (No. 2139a, Sianfu, Shensi, China, August 30, 1914). Wild peaches having larger fruits than the ordinary wild ones, said to come from near Tzewu, to the south of Sianfu, but some also probably collected from trees in gardens which were raised from wild seeds. When seen wild this peach generally assumes a low bush form of spreading habit; when planted in gardens and attended to, it grows into a small tree, reaching a height of 12 to 20 feet, with a smooth trunk of dark mahogany-brown color. The leaves are always much smaller and more slender than in cultivated varieties, while their color is much darker green. They seem to be somewhat less subject to various diseases than the cultivated sorts and

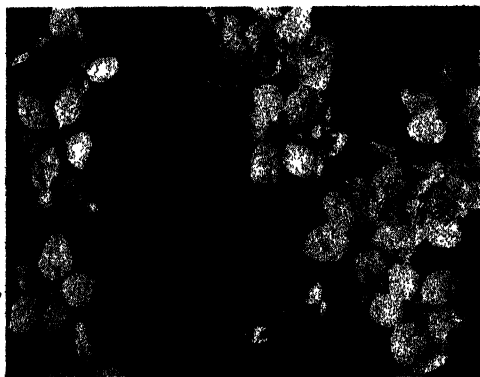


FIG. 1. Flowers of *Prunus kansuensis*.



they are most prolific bearers, although the fruit is of little value on account of its smallness and lack of flavor. In gardens around Sianfu, this wild peach is utilized as a stock for improved varieties. It is also grown as an ornamental; said to be literally covered in spring with multitudes of shell-pink flowers."

Rehder (2) describes *Prunus kansuensis* as being "closely related to *P. persica* which differs in having more finely serrate leaves, more abruptly contracted at base with usually two conspicuous glands at the apex of the petiole, in pubescent winter buds, in the shorter style, and usually larger, pitted and deeply grooved stones with narrow and irregular grooves; while in *P. kansuensis* the stone is not pitted and

the grooves are wider and shallower and fairly regular and parallel in the lower half of the stone. The color of the flowers of the new peach is shell-pink according to Meyers, but in the cultivated specimens before me it is white with only a slight trace of pink in the young bud."



FIG. 2. Tree of *Prunus kansuensis* in full bloom.

#### DESCRIPTION OF PRUNUS KANSUENSIS IN NEW JERSEY

As grown at New Brunswick, New Jersey, P.I. 39428 has shell-pink flowers with long narrow petals. (See Fig. 1.) P.I. 40001 has white flowers with a rounded petal showing a slight trace of pink in the young bud.

*Tree*.—Blake (3) has previously described *Prunus kansuensis* (see Fig. 2) as having a very distinct bushy and willowy habit of growth and being characterized by the development of numerous, strong, upright sucker growths from the base, the bark of the base of these sucker shoots being a light gray and entirely distinct from simi-



FIG. 3. Twigs of *Prunus kansuensis* (left) and of *P. persica* (right) compared.

lar shoots upon *P. persica*. This difference (Fig. 3) is caused by the epidermis of the young twig being ruptured to form a gray colored network upon the formation of the first (outermost) periderm as the current season's growth matures and becomes woody. This condition persists during the winter and may be noticed in lessened degree upon the 2-year-old wood.

**Fruit Buds:**—The glabrous fruit buds are small, pointed, and very numerous with a recorded bud set of 40 to 60 per foot of annual growth, as determined on the basis of the New Jersey standard (4).

**Leaves:**—Large well developed leaves are narrow-lanceolate shaped, 4.0 to 5.5 inches long by 1.0 to 1.2 inches wide, with a characteristic acuminate apex and are generally flat—neither waved nor crinkled. The apex angles of leaves measured with a protractor at 1 inch distance from the tip of the leaf blade are 20 to 24 degrees. The base angles of leaves measured in a similar manner at  $\frac{1}{2}$  inch distance from the base of the leaf blade are 60 to 70 degrees. Few varieties of *Prunus persica* have leaves with either apex angles or base angles as narrow as leaves of *P. kansuensis*. Glands are absent from the short petiole (.15 to .2 inches) which has upturned edges similar to *P. persica*, but are found at the base of the leaf blade in the serrations of the leaf margin. Some are reniform; others imperfectly developed. The leaf color is a light green similar to Hiley or Belle, white-fleshed varieties of *P. persica*.

**Time of Flowering:**—*Prunus kansuensis* was in full bloom on March 26, 1938 and J. H. Hale on April 18, or 23 days later. Earlier records show *P. kansuensis* to have bloomed at least 10 days earlier than J. H. Hale each year. In 1926, fully opened blossoms of *P. kansuensis* were subjected to minimum temperatures of 25 degrees F without injury. Frost resistance of the blossoms as well as early-blooming is characteristic, and a good set of fruit has occurred from blossoms exposed to temperatures of 25 degrees F.



FIG. 4. Fruit of *Prunus kansuensis*, showing large air space about the pit.

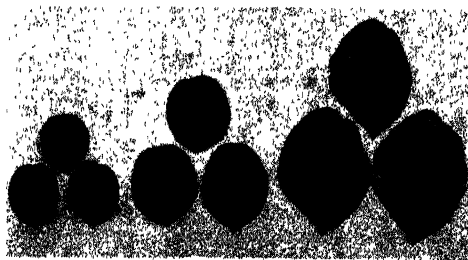


FIG. 5. Pits of *Prunus kansuensis* (left), *P. kansuensis* x J. H. Hale (center), and Hale (right).

**Hardiness:**—During February 1934, temperatures of  $-16$  degrees F caused severe wood injury. *Prunus kansuensis* seems to be no hardier in wood than J. H. Hale and probably is less so, since large well developed trees of both types of *P. kansuensis* were completely killed. During the "open" winter of 1932-33, a minimum temperature of  $-3$  degrees F on February 13, 1933, caused killing of a large percentage of fruit buds upon J. H. Hale and other varieties of *P. persica*. J. H. Hale showed 5 per cent buds alive, but all fruit buds of *P. kansuensis* were killed. Fruit buds upon twigs brought into a warm room during mid-winter are easily forced into bloom. Swelling of the buds upon trees of *P. kansuensis* during mild periods in mid-winter show its rest period to be short or easily broken, which would cause its buds to become increasingly susceptible to low temperatures that might follow.

**Fruit:**—The freestone fruits with a large air space about the pits (Fig. 4) are small and round, with a harsh-feeling pubescence. The flesh is white with red about the pit, and very acid and astringent. The stone (see Fig. 5) is ovoid-ellipsoid, keeled along the dorsal suture, not pitted, and shallowly furrowed with furrows tending to parallel upon the lower half of the stone.

#### FIRST GENERATION HYBRIDS

From crosses made in 1925 by C. H. Connors, five trees of the J. H. Hale x P.I. 39428 cross; and 21 trees of the J. H. Hale x P.I. 40001 cross were secured. These hybrids were like the *Prunus kansuensis* parent in general tree characteristics with a willowy, bushy, suckering habit of growth; but twigs, leaves, and flowers were larger. As 1-year-old seedling trees, the  $F_1$  hybrids made a remarkable growth, some measuring 3,488 inches of total annual linear twig growth. Fifteen hundred to 2,000 inches of total annual linear twig growth is considered

exceptional growth for 1-year-old seedlings of *P. persica*. The distinct light-gray network at the base of sucker shoots typical of *P. kansuensis* (see Fig. 3) was dominant, though a type rather intermediate between the parent species in this respect occurred in some of the hybrids. The fruit buds were intermediate between the parents in pubescence. These hybrids came into full bloom on April 6, 1928, or 26 days earlier than J. H. Hale. Of the J. H. Hale x P.I. 39428 cross, two seedlings had



FIG. 6. Tree of *Prunus kansuensis* x J. H. Hale in full bloom.

large blossoms, two small blossoms and one tree no blossoms. Of the J. H. Hale x P.I. 40001 cross, 13 seedlings had large blossoms, six small blossoms, and one tree no blossoms. All blossoms were pink. The early blooming habit of *P. kansuensis* and blossoms resembling *P. persica* are characteristic of the hybrid seedlings. No pollen-sterile seedlings were observed. The fruits of all F<sub>1</sub> seedlings of J. H. Hale x P.I. 39428 may be described as small, round-oval, medium heavy in pubescence, freestone, and white-fleshed with red about the pit. The edible quality is low with high acid and tannin content. The fruits of the F<sub>1</sub> seedlings of J. H. Hale x P.I. 40001 may be described as small, round-oval, medium in pubescence, freestone, and white-fleshed with red about the pit. Edible quality is low with many seedlings showing acidity or astringency.

The stones of the F<sub>1</sub> seedlings of both crosses are intermediate in size (see Fig. 5) between stones of the parent species. Their general shape is similar to stones of *Prunus kansuensis*. The keeled dorsal sutures of stones of the F<sub>1</sub> seedlings are similar to stones of *P. kansuensis*. Both furrows and pits occur upon stones of the F<sub>1</sub> seedlings. These furrows and pits are deeper than the shallow furrows, without pits, that are characteristic of stones of *P. kansuensis*.

A few trees of an F<sub>2</sub> population fruited in 1938. When complete data are available, a report on second generation progeny of crosses of *Prunus persica* and *P. kansuensis* may be expected.

#### ACKNOWLEDGMENT

The authors wish to acknowledge indebtedness to Dr. C. H. Connors for aid in presenting data from earlier records.

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## Inbreeding Experiments with the Apple

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This material will be published as a bulletin from the Illinois Experiment Station.

**T**HE results of fruiting self-pollinated apple seedlings of various parental combinations from 1909 to date were covered in this report. Attempts were made to secure self-pollinated seedlings in 398 lines. All told, 43,902 flowers were self-pollinated and 2,201 fruits were picked, in which there were 5,468 seeds. When these seeds were planted, only 1,603 germinated but 1,326 seedlings were planted in the test plots. Of these, 832 died or were otherwise eliminated before reaching 5 feet in height. A total of 128 seedlings have been sufficiently vigorous to fruit, to date, and 214 have not fruited as yet. Some of the inbred seedlings are vigorous in growth and fruitful at a relatively early age. In a few of the lines, the third inbred generation has been reached.

# The Immediate Effect of Pollen on the Fruit of the Chestnut

By J. W. MCKAY and H. L. CRANE, *U. S. Horticultural Station, Beltsville, Md.*

THE immediate effect of pollen on the tissues of fruit or seed has received much attention in recent years in several plants of horticultural importance. The majority of the literature on this subject deals with metaxenia, or the immediate effect of pollen on the maternal tissue of fruit or seed, and there are comparatively few references, other than those dealing with *Zea mays* L., and other cereals, to the immediate influence of pollen on the endosperm or embryo of the seed. Blaringhem (1) reported but gave no data on a case of xenia in the chestnut in which time of ripening and size of nut were affected by the kind of pollen used. However, his observations were based upon a small number of hybrid nuts. Nixon (6) reported a striking pollen effect on size and shape of seed in the date, although in this case a metaxenia effect on size and time of ripening of the fruit was of more importance. Harrison (3) concluded that increase in size of cotton seeds in certain crosses was due to heterosis or hybrid vigor rather than xenia. Tufts and Hansen (11) found little variation in size of Bartlett pear seeds resulting from several pollens, but differences in length and breadth of seed were perhaps statistically significant and the result of xenia. Nebel (5) reported that two pollens produce a differential effect on seed length in apples. Rosa (8) showed that the average weight of seeds in melons seemed to be about the same regardless of pollen used.

The work reported here has resulted from observations made in 1937 when it was noticed that a single tree of a variety of Japanese chestnut, *Castanea crenata*, Sieb. and Succ., produced nuts of two sizes when two different pollens were applied, under controlled conditions, to the pistillate flowers of this tree.

## DEVELOPMENT OF THE NUT

The fruit of the chestnut is borne in a spiny involucre called the "burr". One to several nuts, usually three, are produced in each "burr". Each nut develops from a single ovary and normally one ovule develops within to form the seed. The nut is thus both a fruit and a seed. The entire kernel or edible portion of the nut is composed of tissue of the embryo, the endosperm being absorbed in the early growth of the embryo. Size of the nut is determined by the extent of embryo growth although the ovary wall offers some limiting influence. The growth of the embryo beyond the capacity of the ovary wall gives rise to nuts having split shells. Since the nut is filled with little else but tissue of the embryo a differential effect on size of nuts resulting from the use of two pollens on the same tree would constitute xenia.

## EXPERIMENTAL METHODS

The experimental work was done in orchards at Arlington Farm, Virginia, Plant Exploration and Introduction Gardens, Bell, (Glenn

Dale) Maryland, and United States Horticultural Station, Beltsville, Maryland. The effect on nut size of pollen from two varieties of Japanese chestnut and three varieties of Chinese chestnut, *Castanea mollissima* Bl., was investigated during the season of 1938, using selected varieties of these two species as the female parent. The pistillate blossoms were covered with manila or cellulose bags as soon as they could be seen and before there was any chance for pollination. The staminate catkins were enclosed in manila bags before pollen was liberated to prevent its dissipation and contamination. In all varieties worked with, except one, only one tree of each was available and in many cases the trees were not mature enough to bear a large crop. The small size of the pistillate trees and the difficulties experienced in pollination technique resulted in a small number of nuts being harvested in the case of certain crosses. Little is known regarding the period of receptivity of the stigmas, and failure of the pistillate flowers to set fruit is attributed in many cases to application of the pollen either before or after stigma receptivity. Until more definite information is available the proper time of applying the pollen will continue to be a matter of judgment of the investigator as to the time of stigma receptivity. In some instances where a set of nuts is not obtained upon the use of certain pollens, incompatibility of pollen and egg may be responsible for the failure rather than lack of stigma receptivity. This is especially true of interspecific crosses involving wide differences between parental species. Further work will be necessary in order to distinguish between these two factors. Statistical constants calculated from the weights of the nuts harvested in 1938 are given in Table I. Each nut was weighed to the nearest gram and from these data the mean weight, standard deviation and coefficient of variation were computed for each cross. The standard error of the difference between the mean weights of nuts from two crosses was computed according to Snedecor's (9) method of comparing groups of different size. The ratio "difference between mean weights/standard error of difference" gave "t" values from which odds of occurrence of such differences due to chance were obtained from Love's (4) tables.

## RESULTS

The most significant example of a pollen effect on nut size is found in the case of a variety of Japanese chestnut called "male-sterile" because the staminate flowers produce no pollen. During the seasons of 1937 and 1938 pollen from two varieties was placed on bagged pistillate flowers on this tree. The varieties of pollen used were: *Castanea mollissima*, var. C1 bearing small nuts having a mean weight of 6.5 grams, and *C. crenata*, var. Austin bearing large nuts having a mean weight of 26.3 grams.<sup>1</sup> The ratios between the mean weights of the nuts resulting from the Austin pollen divided by the mean weight of the nuts resulting from the C1 pollen were 1.45 and 1.44 in 1937 and 1938,

<sup>1</sup>The mean weights of the open pollinated nuts give a rough indication of the size of the nuts produced by the pollen parents. It should be kept in mind that the size of nuts resulting from open pollination may be determined by the variety of pollen effective as is clearly shown in this paper.

respectively. The difference between the mean weights of nuts produced by these two pollens is four and one half times its standard error and is highly significant.

Pollen of Superb, another variety of Japanese chestnut bearing large nuts, was used on male-sterile in 1938. In comparing the nuts produced by Superb pollen with those produced by C 1 pollen a highly significant difference between mean weight of nuts was obtained, although not as great as between Austin and C 1 pollens, Table I.

TABLE I—STATISTICAL CONSTANTS OF THE WEIGHTS OF NUTS AS AFFECTED BY CERTAIN POLLENS (XENIA) ON VARIETIES OF THE CHINESE AND JAPANESE CHESTNUTS (1938)

Cross*	Total Number of Nuts	Ratio of Larger Nuts to Smaller Nuts	Mean weight of Nuts (Grams) with Standard Error	Standard Deviation	Coefficient of Variation
Male-sterile × Austin	34	1.44	27.12 ± 1.44	8.38 ± 1.02	30.91 ± 4.08
Male-sterile × C 1	26		18.77 ± .83	4.26 ± .59	22.70 ± 3.30
Difference			8.35 ± 1.82		
"t" value			4.66		
Odds			Inf.:1		
Male-sterile × Superb	63	1.33	24.95 ± 1.01	8.06 ± .71	32.33 ± 3.16
Male-sterile × C 1	26		18.77 ± .83	4.26 ± .59	22.70 ± 3.30
Difference			6.18 ± 1.69		
"t" value			3.66		
Odds			8079:1		
Mayseption × No. 2698	45	1.33	10.07 ± .85	5.76 ± .61	57.24 ± 7.75
Mayseption open × No. 2698	43		13.37 ± .82	5.40 ± .58	40.38 ± 5.00
Difference			3.30 ± 1.20		
"t" value			2.74		
Odds			328:1		
F. P. 94 A × Moll. No. 2834	12	1.56	10.41 ± 1.23	4.27 ± .87	41.00 ± 9.67
F. P. 94 A × C 1	51		6.68 ± .69	4.94 ± .48	73.90 ± 10.87
Difference			3.73 ± 1.56		
"t" value			2.38		
Odds			105:1		
Moll. No. 2617 × Superb	19	1.29	10.26 ± .70	3.09 ± .50	30.12 ± 5.30
Moll. No. 2617 × C 1	21		7.95 ± .72	3.33 ± .51	41.88 ± 7.51
Difference			2.31 ± 1.04		
"t" value			2.21		
Odds			73:1		
Superb × Austin	43	1.10	23.88 ± 1.43	9.39 ± 1.01	39.34 ± 4.85
Superb × Moll. No. 2698	33		21.70 ± 1.20	6.89 ± .84	31.77 ± 4.28
Difference			2.18 ± 1.96		
"t" value			1.11		
Odds			6:1		

\*Varieties of: *Castanea crenata*, male-sterile, Austin, Superb, F. P. 94 A; *C. mollissima*, C 1, No. 2617, No. 2698, and No. 2834; *C. sativa*, Mayseption.

In all cases of xenia investigated so far, the effect of a pollen on size of the nuts produced has been in the direction of the size of the nuts characteristic of the pollen parent. Pollen from varieties bearing small nuts when used on varieties normally bearing large nuts produces nuts smaller in size than those of the pistillate tree and *vice-versa*.

Another case of xenia was brought out in a different manner by certain nuts harvested from the variety Mayseption of the European chestnut, *Castanea sativa*, Mill. A large number of pistillate catkins of this variety was bagged before pollen shedding and pollinated later with pollen from a variety of *C. mollissima*, Bl., producing smaller nuts than Mayseption. Of this number, one group was kept under bags and the remainder left unprotected. The unprotected flowers produced nuts that were significantly larger than those under bags that received only the pollen of *C. mollissima*. This increase in size of the nuts from



unprotected flowers is attributed to open-pollination that occurred subsequent to the application of *C. mollissima* pollen. Several trees of varieties that normally produce large nuts are growing near the May-septian tree that was used.

Two other instances of significant pollen effects on nut size are given in Table I. In both cases the differences between mean weights of the nuts of the two groups are smaller than in the examples discussed above due to the fact that these varieties normally produce nuts approximately one-third as large as male-sterile. The variety C 1 normally produces small nuts and when this pollen is used on F.P.94A and *mollissima* No. 2617 significantly smaller nuts result than when these varieties are pollinated with pollen from *mollissima* No. 2834 and Superb. There was no significant difference obtained in the size of Superb nuts resulting from Austin and *mollissima* No. 2698 pollens. This case is given by way of comparison with instances in which significant size differences are obtained.

### DISCUSSION

Differences in nut size obtained when two pollens are used on the same tree are attributed to xenia rather than heterosis. The latter would account for only those cases in which nut size is increased beyond the size of either parent whereas at least one definite instance was found in the chestnut crosses in which the size of a large nut was greatly decreased by the use of a certain pollen. The consistent action of two of the pollens worked with gives great weight to the conclusion that pollen may greatly influence the characters of the kernel in the chestnut. Superb pollen on male-sterile (*Castanea crenata*) and on No. 2617 (*C. mollissima*) produced larger nuts than two other pollens. On the other hand, pollen of C 1 on male-sterile (*C. crenata*), on F.P.94A (*C. crenata*) and on No. 2617 (*C. mollissima*) produced smaller nuts than three other pollens.

The type of xenia described in this paper may have a direct bearing on certain breeding problems with chestnuts. For example, it has long been a common observation that variation exists in the size of nuts harvested from a single tree. Nutrition undoubtedly is responsible for some of these differences, especially when only one or two nuts mature in a burr instead of three. Variation has also been noticed in quality of kernels, sweet and indifferent nuts being produced side by side on the same tree. These variations, however, may be due in many cases to the functioning of several kinds of pollen on an individual tree or variety.

Split shells are likewise regarded as being caused by xenia. Depending on the pollen used, the resulting embryo may grow beyond the normal capacity of the ovary wall, and result in a split in the shell of the nut. The development of two or more ovules within a single ovary conceivably may have some relationship to this phenomenon although no observations have been made.

The connection between xenia and parthenocarpic development of nut and burr is one that should be worked out in the future. In many cases of artificial pollination the burr develops to almost normal size, but the nuts after some development become shriveled and contain no

kernel. Examination of these nuts shows that in many cases embryo and endosperm growth is initiated, but fails to continue for any length of time. The question may be raised whether growth inhibiting factors or factors for incompatibility may not be contributed by the pollen to interrupt early embryo development and result in abortion of the nut. These and other features of sterility in chestnut pollination need further study in view of a possible pollen effect on embryo development.

The initial stages of embryo and endosperm growth apparently are sufficient to stimulate the burr to approximately normal development. This may be interpreted as a metaxenia effect although the underlying causes are not yet sufficiently understood. One other case of a possible metaxenia effect was observed. In the cross F.P.94A x C 1 the hybrid nuts are regular in shape and of uniform brown color. In the cross F.P.94A x No. 2834 the hybrid nuts are slightly angular in shape and of reddish brown color with indistinct stripes of darker brown. The angular shape and striped pattern of the hybrid nuts resulting from No. 2834 pollen apparently are due to action of the pollen on the ovary wall since these characteristics are typical of the male parent. The shell of the nut thus seems to be subject to pollen influence, and since it develops from maternal tissue this would constitute a clear case of metaxenia. The number of nuts harvested from this cross was small, however, and since it is the only case of this kind observed, further work is needed before conclusions can be drawn.

Self-unfruitfulness in the chestnut has been observed by several investigators (2, 7, 10), and it is considered that most, if not all, varieties and species are self-sterile. From the genetic standpoint it thus becomes difficult if not impossible to obtain true-breeding varieties in this group of tree fruits. Future investigations concerning the effect of pollen on size and quality of nuts must be based upon empirical methods since the genetic constitution of existing varieties is unknown. It is possible, however, that pollination relationships may be worked out between varieties so that when two are planted together in the orchard they will pollinate each other and produce nuts of uniform size and quality that are superior to present heterogeneous yields.

### SUMMARY

The discovery in 1937 that two pollens produce nuts of different size on a single tree suggested the testing of several pollens on different species and varieties of chestnut (*Castanea*). Cases are described in which differences in mean weights of nuts produced by a certain variety as a result of two pollens are statistically significant. This immediate effect of pollen on the weight of the nut is interpreted as an influence of the pollen on embryo development, and is a type of xenia that is not frequently met with in horticultural plants.

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## A Note on Natural and Colchicine-Induced Polypleidy in Peaches

By HAIG DERMEN and D. H. SCOTT, *U. S. Horticulture Station, Beltsville, Md.*

A TRIPLOID peach (*Prunus persica* Batsch) seedling and another presumably a sectorial diploid-tetraploid were discovered in two lots of peach seedlings by examing the leaves for size of stomata.<sup>1</sup> The triploid individual, an open pollinated seedling of Golden Jubilee, was found in a group of 53 seedlings which were grown from some experimental material subjected to cold and heat treatments. In other experiments, a group of 186 young seedlings were treated with various concentrations of colchicine for different lengths of time. The probable sectorial tetraploid appeared in a group of seedlings from a hybrid, Tuskena x Crawford, treated with 1 per cent colchicine (by complete immersion of material in the solution) for 4 hours.

The triploid found among the temperature treated plants probably resulted from a diploid and haploid gametic fusion, independent of cold or heat treatments. Exposure to heat and cold was so timed that embryo sac development in the young fruits was believed to be complete, and presumably zygote development was in progress. Had the heat and cold treatment affected chromosome number in the zygote, only doubling, resulting in a tetraploid seedling, would be likely to occur.

The length of stomata in the leaves of the triploid seedling was  $45.70\ \mu$  with a standard error of 0.32. The possible tetraploid sector had stomatal length of  $50.70\ \mu \pm 0.39$ ; leaves from the diploid sector of the same plant had stomata measuring  $36.85\ \mu \pm 0.28$ . Measurements of stomatal length on comparable sized leaves of diploid seedlings showed a range from  $32.50\ \mu \pm 0.22$  for the smallest to  $37.95\ \mu \pm 0.29$  for the largest, but leaves of most of the seedlings had stomata  $36\ \mu$  to  $37\ \mu$  long.

Triploidy was confirmed in the one plant by chromosome examination of five root-tips. Examination of nine root-tips of the plant believed to be a diploid-tetraploid sectorial chimera showed only the diploid number of chromosomes. Suitable material for making actual counts of chromosomes in the tetraploid sectorial part of the tree is not yet available.

So far as can be determined from the literature this is the first report of polypleidy in peaches. Also this may be the first time that polypleidy in a woody plant has been induced by colchicine technique. The value of the material for fruit or breeding purposes remains to be determined.

<sup>1</sup>This technique was found practicable for peaches, since all the known varieties belong to one species. In other cases, when dealing with more complex material, this same technique may not prove as helpful in the investigation of polypleidy. The cytological uniformity of peaches was earlier indicated by H. Dermen. *Proc. Amer. Soc. Hort. Sci.* 35: 96-103. 1938.

## Colchicine-Induced Tetraploid and 16-Ploid Strawberries

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THE diploid number of chromosomes in strawberries (*Fragaria*) is  $2n = 14$  and the highest polyploid number is octoploid,  $8n = 56$  chromosomes. For experiments to induce polyploidy by the use of colchicine, *Fragaria vesca*, the Alpine strawberry, a diploid species, and the commercial variety Dorsett, an octoploid, were used.

In November, 1937, seeds of *Fragaria vesca* were kept in a 0.2 per cent colchicine solution for periods varying from 18 hours to several days and not a single plant was obtained that showed even the characteristic external effect of colchicine, usually apparent at least in the first leaf of the seedlings. Some seeds were kept immersed in a 0.2 per cent solution in a petri-dish and began to germinate in the solution by the ninth day. A hundred of these were planted, but none grew further than the cotyledon stage, and eventually all died.

Entirely or partially tetraploid *Fragaria vesca* plants were obtained in the following way: (a) Over one hundred seeds of *F. vesca* were germinated in a petri-dish on filter paper moistened with water. After the seeds had germinated, a 0.2 per cent solution of colchicine was poured on the germinated seeds, and they were kept submerged in the solution for 24 hours. Out of a hundred seedlings planted only one seedling survived, the rest dying at the cotyledon stage. This seedling was a tetraploid. (b) Eight partially  $4n$  plants were obtained from 43 young seedlings which had been cultured as above but which were treated with 1 per cent colchicine for 3 hours. (c) Seven plants less affected than in (b) were obtained from 48 seedlings germinated as outlined above and treated with a 0.2 per cent solution for 8 hours.

### 16-PLOID PLANTS

In January, 1938, seeds of the Dorsett strawberry were germinated on moist filter paper in a petri-dish. Forty-five 1- to 3-day-old seedlings were treated with 1 per cent colchicine for 5 hours, and 98 1-day-old seedlings were treated with a 0.5 per cent solution for 6 hours. From the first group we now have 14 plants growing, and from the second 29 plants. From a preliminary examination of three plants treated with a 1 per cent solution, it was found that one was presumably entirely 16-ploid, while the other two were mixed, having  $8n$  as well as  $16n$  root-tips. After this discovery all the treated plants, 43 in number, were allowed to grow runners from which six plants of each were propagated in order to isolate possible  $16n$  plants. We now possess six runner plants that are apparently 16-ploids, judging from root-tip examinations, and two plants with mixed  $8n$  and  $16n$  tissues. In some cases from the same plant we have isolated both  $8n$  and  $16n$  plants. These will be of interest in comparing their morphological and horticultural characteristics, their fertility, and so on. So far, only 50

of the runner plants have been examined cytologically and 200 remain to be studied.

### TETRAPLOID OFFSPRING

From the seeds of three wholly or partially  $4n$  *Fragaria vesca* plants 124 seedlings were raised. In an examination of a sample of a few root-tips taken from these seedlings, one root-tip had  $3n$  number of chromosomes, while the remaining root-tips were of  $4n$  constitution. This indicates that some of these seedlings are triploids. They are assumed to result from a cross of diploid by tetraploid,<sup>1</sup> the diploid possibly being a sector in one of the three *F. vesca* plants. It will now be necessary to examine all 124 plants to separate out different classes of polyploids.

### TREATING RUNNER TIPS

Dorsett runner tips on which roots had developed were treated by immersing for 6 hours with 1.0, 0.5, 0.2, 0.1, and 0.05 per cent solutions of colchicine. All the samples of root-tips, except the one treated with the 0.1 per cent solution, contained mixed tissues with  $8n$  and  $16n$  cells. This result may indicate that by treating runner tips one may secure doubling of chromosome number in known varieties. In many cases this would be preferable to treating seedlings which vary genetically from the parent variety.

In polyploidy experiments, changes of chromosome number cannot always be determined by gross similarity or differences between the stock plant and treated runner plants.<sup>2</sup> Microscopic examination of chromosome number is the only certain method of determining whether or not such a modification has occurred.

At the United States Horticultural Station at Beltsville, Md., we now have strawberry plants with chromosome numbers  $2n$ ,  $3n$ ,  $4n$ ,  $5n$ ,  $6n$ ,  $8n$ , and  $16n$ . The  $4n$  and  $16n$  strains were obtained directly from colchicine treatments, and the  $3n$  strain from  $2n \times 4n$  crosses. Four  $5n$  plants resulted from a cross between *Fragaria vesca* and Dorsett. The  $6n$  plants are seedlings of *F. moschata* and have proved to be both male and female sterile and could not be used in breeding or treating seedlings with colchicine solution. Runner-tips may be treated to see if their sterility can be modified. Crosses have been made of  $2n \times 4n$ ,  $2n \times 8n$ , and  $4n \times 8n$ , and  $4n$  plants have been selfed. We now have 400 seedlings resulting from these crosses, which were treated with 0.5 to 0.2 per cent colchicine for 3 to 6 hours. If successful, these hybrids and treated seedlings should give us much information on the effect of polyploidy in the strawberry.

<sup>1</sup>In strawberry crosses the higher number was used as pollenizer and low number as female. The reverse does not seem to be successful.

<sup>2</sup>The change from  $2n$  *Fragaria vesca* to  $4n$  was easily detectable. The tetraploid parts had distinctly broader and somewhat larger leaves with deeper, wider serrations than the diploid. In Dorsett seedlings it is not possible yet to separate a  $16n$  runner plant from its  $8n$  sib on such a basis as in *F. vesca*. At this time we do not know if there will develop later other features which may help one to separate  $16n$  from  $8n$  runner plants.

## Red Raspberry Breeding for Southern Adaptation

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THE commercial production of red raspberries in the cooler parts of the southern states usually requires special practices that are not commonly followed by growers farther north. The Georgia Experiment Station (1), as well as other stations in the South, report a marked advantage in mulching. Recent studies at the Tennessee Station suggest that this is due partly to a more uniform moisture supply and partly to the prevention of very high soil temperatures. Leaf spot (*Septoria Rubi* Westd.) is especially serious in this section, often requiring as many as four applications of bordeaux mixture for commercial control. Northern varieties, unless they are given unusual care, lose a large part of their foliage in August, which seriously reduces the vigor of the plant and results in cane-dying during the winter season. Southern markets are poorly supplied with this tasty fruit. There is therefore not only an unfilled demand in this section, but the possibility of shipping to northern markets, since the crop ripens during May and June.

The Van Fleet variety, now considered a cross between Cuthbert and *Rubus kuntzeanus*, was introduced for this part of the United States, but its fruit lacks commercial quality. The plants are very vigorous and show considerable adaptation to southern conditions. About 8 or 10 years ago,<sup>1</sup> the Tennessee Station began experiments to determine the possibilities of *R. kuntzeanus* hybrids. A selfed population of Van Fleet that fruited in 1931 was far from promising. More than 90 per cent were discarded with mosaic, and none of the seedlings that fruited were superior to Van Fleet in fruit characters. At the present time only one of the selfed lines that were selected from this population survive, and it appears to be sterile.

Back crossing using such varieties as Viking, Chief, Cayuga, and Latham, should result in improved commercial quality of fruit and increased resistance to mosaic diseases. These varieties, both as maternal and paternal parents, were used in the first crosses, and a population of about 2,500 were fruited. This group of seedlings contained one-quarter *Rubus kuntzeanus*. Twenty-two per cent of the seedlings showed leaf spot injury the first season, and this increased in severity the second season. No fungicides of any kind were applied to control diseases. Curl was present among the progenies of all the crosses, but averaged only 5 per cent infected plants. Mosaic continued to be a very destructive disease, affecting nearly 50 per cent of all the seedlings. This group, however, showed a marked decrease in infection when compared with the selfed population of Van Fleet mentioned above.

Over 40 per cent of the seedlings in this population produced fruit that was not red, 5 per cent were classed as large-fruited, and less than 20 per cent had coherent drupelets. Eleven per cent were classed as

<sup>1</sup>The records previous to 1931 were kept by J. A. McClintock and H. L. Fackler. James Tyer in 1933, Kay Beach in 1934, and L. A. Fisher in 1935, assisted with this project.

richly flavored, and 19 per cent firm fruited. Two per cent were considered promising and were saved, but none have proved worthy of naming and introducing.

A number of the more promising seedlings from the first back-cross were used as parents in the second. Lloyd George was chosen as the other parent in all cases. Reciprocal crosses were made. This population numbered about 2,700, and was managed without any insect or disease control. Mosaic varied from a trace in (Latham Van Fleet) 181 x Lloyd George to over 60 per cent infection in (Latham Van Fleet) 221 x Lloyd George, averaging 31 per cent. Curl-infected seedlings varied in the second back cross but averaged 4.8 per cent, or nearly the same as in the first group. Leaf spot infection increased the first year to as high as 88 per cent in some crosses, and averaged 57 per cent among all crosses. By the end of the second fruiting season it was almost impossible to find a seedling that did not show a few leaf spot lesions.

Progenies containing one-eighth *Rubus kuntzeanus* (the second back cross) produced many seedlings with fruit of excellent commercial quality, often approaching Cuthbert in flavor and firmness. Of these seedlings, 23.9 per cent were classified as large or very large-fruited, and 31 per cent had coherent drupelets and all were red-fruited, except an occasional seedling. Of the progenies of these crosses, 20.6 per cent were saved as superior seedlings for further study. Several varieties already have been sent out for grower tests. At least one fall-fruited selection is likely to be named and introduced.

TABLE I—CANE DYING\* IN RED RASPBERRY SELECTIONS (WINTER 1937-38)

♀	Cross	♂	Number of Plants	Less Than 1 Foot (Per Cent)	1 Foot and Under 2½ Feet (Per Cent)	2½ Feet and Under 4 Feet (Per Cent)	Over 4 Feet (Per Cent)
Lloyd George	×	(Viking × Van Fleet seedling) 169	159	22.0	25.1	31.8	22.6
(Viking × Van Fleet seedling) 169	×	Lloyd George	74	56.7	17.5	17.5	8.1
(Latham × Van Fleet seedling) 181	×	Lloyd George	142	53.5	32.3	13.3	0.7

\*Causes not determined, but occurs in the Van Fleet variety as well as its progenies.

Table I indicates the extent of dying back of canes among the selections containing one-eighth *Rubus kuntzeanus*. This is very serious, and unless it can be reduced greatly by spraying for leaf spot control, it will cause many superior seedlings to be discarded. This cane winter killing under southern conditions is due in part, however, to the practice of starting growth during warm spells in midwinter. Table II is an effort to measure this factor with four of these crosses. More than half of all the progenies showed growth on January 29, 1937, and were later injured by cold.

Pollen troubles including sterility have long been noticed among bramble fruits and was constantly noted in this breeding project. A preliminary study of pollen and pollination among superior seedling selections was started in 1938. Data on three of these crosses are presented in Table III. Both self- and inter-sterility were found, especially



TABLE II—EXTENT OF STARTING GROWTH\* IN RASPBERRY SEEDLINGS  
(JANUARY 29, 1937)

♀	Cross	♂	Total Number of Plants	Dor- mant (Per Cent)	Buds Swelling (Per Cent)	Showing Growth (Per Cent)	Growth ½ inch and Under (Per Cent)	Growth Over ½ Inch (Per Cent)
Lloyd George	×(Viking × Van Fleet)	seedling 169	323	3.7	26.0	44.8	23.5	1.8
(Viking × Van Fleet)	seedling 169 ×	Lloyd George	844	6.8	38.5	30.8	23.8	None
(Latham × Van Fleet)	seedling 181 ×	Lloyd George	1056	1.4	8.8	32.1	56.9	0.6
(Latham × Van Fleet)	seedling 48 ×	Lloyd George	220	9.0	32.7	36.8	21.3	None

\*The earlier starting seedlings nearly always show cold injury under Tennessee conditions.

in certain crosses. The pollen of some seedlings was very fine and in other cases defective. No data were obtained on unselected progeny groups, but sterility accounted for the discarding of large numbers of seedlings, as having defective fruit.

TABLE III—POLLINATION STUDIES WITH RED RASPBERRY SELECTIONS  
(SEASON OF 1938)

♀	Cross	♂	Number of Selections	Self- Fruitful (Per Cent)	Partially Self- Fruitful (Per Cent)	Self- Sterile (Per Cent)
(Viking × Van Fleet)	seedling 169 × Lloyd George		12	41.6	8.3	50.0
Lloyd George	×(Viking × Van Fleet)	seedling 169	21	95.2	None	4.7
(Latham × Van Fleet)	seedling 181 × Lloyd George		12	66.6	25.0	8.3

## SUMMARY AND TENTATIVE CONCLUSIONS

A selfed population of the Van Fleet raspberry gave progenies highly susceptible to mosaic and fruit of undesirable quality. A back-cross on several cultivated varieties produced a population that was less susceptible to mosaic but more susceptible to leaf spot than seedlings produced by selfing Van Fleet. The fruit produced was still of too low commercial quality to be valuable in the general market. A second back-cross with Lloyd George as a parent, produced a seedling population averaging high in leaf spot susceptibility and low in mosaic injury. These plants had good vigor, but much less than Van Fleet. The quality of fruit produced by the better seedlings compared favorably with commercial varieties commonly grown. The best selections from the latter population promises to furnish varieties well adapted to the climatic belt represented by Tennessee. These varieties may or may not need fungicidal sprays to control leaf spot.

## LITERATURE CITED

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## Some Results of Self-Pollination of the Highbush Blueberry at Whitesbog, New Jersey<sup>1</sup>

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THE senior author, from 1911 to 1928, worked in close association with Dr. F. V. Coville of the United States Department of Agriculture, supplying him with selected wild bushes which constituted the major portion of his blueberry breeding stocks. During this period she had charge of approximately 35,000 seedlings which were tested for the Department at Whitesbog, more than 90 per cent of all produced by Dr. Coville up to 1928. In 1928, the senior author began independent blueberry breeding, the number of different crosses made from 1928 to 1937 being 298, and the number of seedlings produced from these crosses 147,000. The objective of the breeding work at Whitesbog has been the development of better commercial varieties of blueberries.

Dr. Coville (3) has stated, "When blueberry flowers are pollinated with pollen from their own bush the berries are fewer, smaller, and later in maturing than when the pollen comes from another bush. Some bushes are almost completely sterile to their own pollen . . . It is important, therefore, that a plantation should not be made up wholly from cuttings from one bush."

The senior author's extensive field observations had lead her to concur fully with Dr. Coville. In consequence no thought was given to the desirability of experimenting with self-pollination until the question was raised by the work of Merrill (4) who concluded that "self-pollination gives satisfactory commercial sets in those varieties of highbush blueberry investigated." In order to determine the self-fertility of certain varieties at Whitesbog, a number of those which were being used in the breeding program were self-pollinated in 1937. As Rubel was not included among these, it and several other varieties were self-pollinated in 1938.

### METHODS

The breeding work at Whitesbog has all been done on bushes in the open field. The method employed in protecting the blossoms from contamination by undesired pollen was as follows. The clusters to be pollinated were selected after the first few flowers had opened and all open flowers were removed with forceps. Each cluster was then covered with a manilla paper bag which was folded closely about the stem, secured by large pins through the folds, and left in place for 3 to 5 days before the crosses were made.

Pollen was collected from bagged flowers or from flowering stems kept in water in the house where blossoms continued to open for several

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<sup>1</sup>Journal Series paper of the New Jersey Agricultural Experiment Station, Department of Pomology.

days. The open flowers were gently reached from the stems with curved forceps. The pollen was collected in No. 1 gelatine capsules by twirling the blossom between the thumb and forefinger over the open capsule. Some flowers yielded a perceptible shower of pollen and by twirling many flowers sufficient pollen was secured to fill the capsule to a depth of  $\frac{1}{16}$  to  $\frac{1}{8}$  inch. When pollen from one variety was to be used on several seed parents a separate capsule of pollen was collected for each. This is a safeguard against accidents of which, when working outdoors, high winds are the most frequent cause. The capsules of pollen were placed in marked envelopes, the envelopes placed in a covered jar, and the jar in a refrigerator. Pollen thus kept dry and cold will retain its viability for a considerable period. The senior author has used it with good results after it has been in the refrigerator for a week, and was told by Dr. Coville that he had secured good results with pollen more than a month old.

When each pollination was made the bag was removed from the cluster, all small buds were picked off with the forceps, and the corolla and stamens were removed with the same instrument. The pollen from the capsule was then applied with a tiny spatula made by flattening the wire of a paper clip. It has seemed desirable to place the pollen on the stigma with a definite though gentle pressure.

When weather is favorable for the secretion of nectar, bees will continue to visit blueberry blossoms for at least 2 days after the removal of the corolla and stamens. Therefore, after the pollination of each cluster was completed the bag was again fastened over it and left for 3 or 4 days. It was then removed to permit the normal growth of the leafy shoots surrounding each cluster of flowers.

When the berries were nearly ripe, they were covered again to prevent their being taken by birds or knocked off by high winds. By this time the leafy shoots had grown so long that it was impractical to cover the clusters with bags similar to those used at the time of pollination. Instead it has been found convenient to use pieces of fine mosquito netting, secured about each cluster by pins. This method protects the hand pollinated berries from the hazards mentioned above but does not secure them against occasional attacks by insects or infection by mummy berry fungus. Without the protection afforded by the netting a large percentage of the berries of early varieties hand pollinated in 1938 would have been lost.

The results of self- and cross-pollination with certain varieties are shown in Table I. The berries were classified as to size by being placed on a metal gauge, those which rested on the 20 millimeter hole in the gauge being placed in the first group while those which dropped through the 20 millimeter hole but rested on the 19 millimeter hole were classified as 19 millimeter. The seeds in the berries resulting from certain self-pollinations were counted, whereas in others the seeds were planted and the resulting seedlings only were counted. Seeds from the berries resulting from cross-pollination were planted and the resulting seedlings only were counted.

The data in Table I indicate that, in many cases at least, the per cent of total flowers self-pollinated which set fruit was not significantly

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TABLE I—PER CENT SET, SIZE OF BERRIES, AND NUMBER OF SEEDS, OR SEEDLINGS FROM SELF- AND CROSS-POLLINATIONS AT WHITESBOG, NEW JERSEY

Cross	Flowers Pollinated	Set (Per Cent)	Number of Berries in each Size Class; (Mm.)									Number of Seedlings				
			20	19	18	17	16	15	14	13	12					
1937 Pollinations																
Sam Xself	27	48.1					1	1	4	4	4	2	139s*			
Sam XGrover	73	79.5					1	1	19	11	12	5	9	1520		
Grover Xself	5	100.0											5	0		
Grover XSam	53	69.8					4	9	4	7	5	2	6	300		
Harding Xself	36	0.0												0		
Harding XHaines No. 4	82	50.0	3	8	5	6	7	8	3	3	1	22		840		
Haines No. 4 Xself	28	89.3								3	9	13		110s		
Haines No. 4 XHarding	72	66.7						5	22	10	7	2	2	1000		
Haines No. 4 XBrooks	65	56.9						4	8	8	7	10		300		
Brooks Xself	23	43.5											10	19s		
Brooks XHaines No. 4	55	74.5							1	5	12	6	17	300		
Concord Xself	18	66.7						3	2	2	2	1	2	44		
Concord X29-17A	104	92.3		25	17	25	8	3	3			18		2031		
1552H Xself	24	66.7											16	2		
1552H X29-17A	49	67.3					1	7	9	7	2	2	5	595		
1552H X1613A	77	71.4					18	19	4	5	8			1102		
1552H X1239E	59	67.8					1	2	5	11	4	6	11	355		
Stanley Xself	24	87.5							3	6	4	3	5	4		
Stanley X2505A	114	84.2		16	17	13	16	4	3	1	26			706		
Stanley X29-17A	106	85.8			1	4	26	20	12	5	23			1640		
Stanley X29-28B	86	95.3				2	13	25	23	8	6	4		540		
Stanley X29-28A	73	71.2	1	1	5	5	24	10	6		5			374		
1239E Xself	31	39.0											12	B.D.†		
1239E X1552H	65	93.8							5	6	14	8	13	300		
1239E XJersey	52	90.4							6	11	4	8	4	14	264	
1239E X1437C	67	80.6	3	6	13	16	7	2					7		1110	
1239E X1617H	85	74.1				1	11	14	21	7	3	3	3		550	
1239E X2505F	95	72.6					7	23	21	9	3		6		1022	
1239E X2505A	132	93.9	1	6	20	32	18	10	11		3	23			1580	
1437C Xself	21	61.9												13	B.D.	
1437C X29-17A	66	63.6												1	B.D.	
1437C X1239E	42	69.0		2	10	6	5	3	1	1				1	300	
1938 Pollinations																
Rubel Xself	42	71.4									4	14	6	6	—	
Rubel X1552H	36	63.9									4	9	4	1	—	
1613A Xself	36	94.4								1	7	7	1	6	12	—
1613A X28-8A	71	81.7					2	6	21	5	1	1		6		—
1613A X29-39D	82	100.0						8	22	6	1	6		14		—
1613A X29-39C	69	73.9						4	8	5	5	1		14		—
1613A X29-39B	74	78.4							16	12	8	4		2		—
1613A X29-39A	59	89.8						4	12	9	6			5		—
1613A XStanley	79	81.0						8	10	8	4	1		5		—
1613A X1552H	76	72.4							10	10	9	9				—
2505A Xself	34	73.5						2	1	4	7	3		8		—
2505A X1613A	76	86.8		3	10	12	18	7	4	3				9		—
2505A X28-8A	58	77.6		4	3	8	8	12	3	2				5		—

\*s, seed count, seeds not planted

†B.D., berries discarded, seeds not counted.

different from the per cent set with cross-pollination. In all of the progenies, however, with the possible exception of 1437C selfed compared with 1437C x 29-17A, the berries resulting from self-pollination were distinctly smaller than those resulting from cross-pollination and

were usually too small to be considered of commercially desirable size. Furthermore, the small berries resulting from self-pollination were usually still green at the time when the large berries resulting from cross-pollination were ripe.

Merrill (4) stated that he found no relationship between size of berry and number of seeds. In this connection there are presented some data secured by the senior author in 1935. Fruit from three different crosses was picked on July 3, and the berries classified according to size. The seeds from the berries of each size class were washed out separately. When sufficiently dry to handle, the seeds of each group were divided, with the aid of a small magnifying glass, into "Large" and "Small" and counted, the results being shown in Table II. After being counted the "Large" and "Small" seeds from each pollination were planted making two groups for each cross.

TABLE II—NUMBER OF SEEDS IN BLUEBERRIES OF DIFFERENT SIZES, POLLINATIONS OF 1935, WHITESBOG, NEW JERSEY

Cross	Number of Berries	Diameter (Mm)	Average Number Large Seeds per Berry	Average Number Small Seeds per Berry	Average Number of Seeds per Berry
1437C x Haines No. 4 ...	2	20	27.5	27.5	55.0
	6	19	26.0	37.0	63.0
	9	18	27.8	33.1	60.9
	11	17	20.0	38.1	58.1
	3	16	15.0	40.7	55.7
1437C x 2506B . . . . .	6	16	10.8	30.8	41.7
	1	19	22.9	45.1	68.0
	6	18			
	16	17	21.9	33.7	55.6
	10	16	14.5	43.0	57.5
1437C x 2505A . . . . .	3	16	8.3	25.0	33.3
	2	18			
	9	17	24.8	30.9	55.7
	9	16			
	7	15	17.7	21.2	38.9

It is evident from the data in Table II that, in these crosses at least, the larger berries contained more seeds. It would seem logical to think, therefore, that anything, such as better pollination, which might tend to increase the average number of seeds per berry would also tend to increase the average size of berries.

Counts made in April of 1936 showed that, from the cross 1437C x Haines No. 4, the 791 large seeds had produced 474 plants, whereas 1,301 small seeds gave only 450 plants. Plants from the large seeds were about 15 per cent larger at this time than the plants from the small seeds. From the cross 1437 x 2506B, the 680 large seeds produced 630 plants whereas 1,361 small seeds gave 559 plants which were slightly smaller than plants from the large seeds.

## DISCUSSION

The results obtained in these experiments agree with the findings of Coville (3) and Beckwith (2), that self-pollinated blueberries are smaller and later in maturing than the berries resulting from cross-pollination. Bailey (1) compared self-pollination with open-pollination of a number of varieties in Massachusetts, during three different seasons, and stated that Rubel gave the best performance when self-

pollinated but that in none of the three seasons was a satisfactory commercial crop produced. He also found that there was a tendency, for certain varieties at least, to set small berries when self-pollinated.

On the other hand, the data presented in this paper are not in agreement with the results of Merrill (4) who reported that, under conditions in Michigan, Rubel, Cabot, Adams, and Pioneer were sufficiently self-fruitful to give a satisfactory crop although in most cases a slightly better set was secured by cross-pollination. Furthermore, Merrill found the selfed berries to be as large in every case as the crossed berries and that they matured in their normal season. The differences between the results secured by Merrill and those reported in this paper might possibly be explained on the basis of different environmental conditions or varietal differences. The only variety used in both experiments was Rubel, which gave especially good yields when self-pollinated in Michigan. In New Jersey, Rubel selfed gave a good set but smaller size and later maturity than when it was cross-pollinated, although the number of pollinations was not large.

From the evidence presented in this paper it would seem advisable, under New Jersey conditions at least, to provide for adequate cross-pollination in blueberry plantings. In most of the crosses there was a satisfactory set and normal size regardless of the kind of pollen used. There is an indication of incompatibility, however, in the cross 1437C x 29-17A. In the cross 1239E x 1552H the resulting berries were slightly smaller than where other pollen varieties were used and they were distinctly slower in ripening, possibly indicating some degree of incompatibility. There is a possibility, therefore, that two varieties planted together to insure cross-pollination might prove to be incompatible but most varietal combinations would probably be satisfactory from the standpoint of pollination.

#### SUMMARY

The set obtained by self- and cross-pollination of flowers of several blueberry varieties and the size of the resulting berries were studied. A poor set was obtained from certain self-pollinations but on the average the per cent was about as good from self- as from cross-pollinations. The berries resulting from self-pollination were consistently smaller than those resulting from cross-pollination and in some cases remained hard and green for several days after the larger, cross-pollinated fruits had ripened. The large berries of certain crosses studied contained more seeds than the smaller berries, the number of large seeds being roughly proportional to the size of the berry.

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## Pollen Longevity Studies with Deciduous Fruits

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THE advances in plant breeding have made obvious the desirability of extended information concerning pollen. This is especially true in regard to pollen longevity; for pollen which will retain its viability for extended periods of time, either naturally or under controlled storage conditions, can be used in crossing varieties which have different blooming periods.

Many of the studies on pollen longevity have been reviewed by Knowlton, Holman and Brubaker, and Nebel and Ruttle. In general, these studies have considered the relation to pollen longevity of humidity, Holman and Brubaker (9), Pfundt (14), Knowlton (10), Nebel and Ruttle (11), Adams (1), Pfeiffer (12), Hill (7), Traub and O'Rork (16); of temperature, Pfeiffer (13), Nebel and Ruttle (11), Pfundt (14), Knowlton (10), Goff (6), Traub and O'Rork (16); of varying pressure, Pfeiffer (13), Knowlton (10); of culture media, Sandsten (15), Adams (1); of shipment conditions, Kellerman (9), Patterson (12); and of physiological conditions, Brink (2-5), Sandsten (15), Knowlton (10).

The present study has been confined to the inter-relation of temperature and humidity to pollen longevity, and was begun in the spring of 1937. Since the tests are still being carried on, this paper is a progress report.

Nineteen different pollen were used, 13 from the genus *Prunus*, three from *Pyrus*, two from *Cydonia*, and one from *Pistacia*. Unopened flowers were collected in the field and taken to the laboratory, where the anthers were removed and allowed to dry in partially opened Petri dishes. The pollen was then stored in 15 x 30 mm shell vials, loosely stoppered with cotton. The vials were stored in tightly sealed fruit jars. The calculated relative humidities of 0 per cent (Concentrated  $H_2SO_4$ ), 25 and 50 per cent were secured with sulphuric acid-water mixtures. Each of these humidities was kept at four different temperatures, 32 degrees F, 36 degrees F, 45 degrees F, and room or 65 to 80 degrees F. A sample of each pollen was maintained at 10 degrees F with no humidity regulation and another at room temperature and humidity as a control. These conditions have been maintained since the beginning of the tests, except for a short period in the summers of both 1937 and 1938 when the jars were transferred to other storage rooms where the temperatures were approximately the same, but slightly less constant. To date, records on percent of germination have been taken at five intervals: (I) May and June, 1937; (II) August, 1937; (III) November and December, 1937; (IV) June, 1938; and, (V) September, 1938. These dates are approximately 40, 125, 245, 430, and 550 days after collection, respectively.

<sup>1</sup>In cooperation with the Division of Fruit and Vegetable Crops and Diseases, United States Department of Agriculture.



A 15 per cent sucrose solution with the hanging drop technique was used to culture the pollen for the counts made in 1937; while a 2 per cent agar medium containing 15 per cent sucrose was substituted in 1938 for the sucrose solution. Counts were made 12 to 18 hours after culturing. Duplicate counts of 125 grains were made; a total of over 300,000 to date. In spite of uniformity in technique and of careful selection of blossoms, considerable variability and irregularity in germination appeared within the various varieties, so that the experimental error is undoubtedly high. Nebel and Ruttle (11), Holman and Brubaker (8) and others have also found this to be true.

The reason for the change in culture media from sucrose solution to sucrose agar may be mentioned. The success obtained by other workers with the sucrose hanging drop culture in pollen germination and its use at Davis for many years led to its use in the early part of the problem. However, the rather erratic germination behavior of the pollens in the sucrose solution lead to experimental tests with sucrose agar in the hope that a more consistent response of the pollens could be obtained. The results of these tests encouraged the use of this medium for counts IV and V (1938). The percentage of germination for these two counts (430 and 550 days, respectively, after collection) was in general higher than that of counts II and III (125 and 245 days, respectively, after collection), and in some cases even higher than the counts made at the time of collection. A comparison of germination percentages between the original count (in sucrose solution) and counts IV and V (in sucrose agar) is illustrated in Table I. This is contrary to what might be expected, in view of anticipated mortality, even under optimum conditions contributing to longevity. It would appear from

TABLE I—A COMPARISON OF POLLEN GERMINATION OF THE 19 VARIETIES STUDIED

Variety	Germination at Time of Collection (Per Cent)	Highest Germination After 430 Days Storage (Per Cent)	Storage Conditions for Highest Germination After 430 Days Storage (Degrees F Relative humidity)	Highest Germination After 550 Days Storage (Per Cent)	Storage Conditions for Highest Germination After 550 Days Storage (Degrees F Relative humidity)
Thompson's Early Apricot . .	49.25	31.20	36-25	25.60	36-25
Milan Peach . . . . .	84.75	84.80	32-50	41.60	36-25
Humboldt Nectarine . . . .	80.00	84.00	36-25	63.20	36-25
Pond plum . . . . .	12.00	52.40	32-25	43.61	32-25
Mingo plum . . . . .	0.75	45.60	36-25	37.20	36-25
Yellow Egg plum . . . . .	8.00	57.20	45-25	51.60	32-25
Belle of Orleans cherry . . .	58.00	68.40	36-0	40.40	36-0
Lewelling cherry . . . . .	17.75	20.00	45-25	8.00	45-25
Knight cherry . . . . .	54.50	72.40	36-25	69.60	36-50
Royal Duke cherry . . . . .	2.75			10.00	36-25
English Morello cherry . . .	16.50	27.60	32-25	30.40	32-25
Seedling Almond . . . . .	69.50	60.40	36-0	52.80	36-25
Pyrus phaeocarpa . . . . .	61.25			46.00	36-0
Winter Nellis pear . . . . .		95.20	32-25	90.00	32-25
Gravenstein apple . . . . .	14.00	3.20	45-25	2.80	45-0
White Astrachan apple . . .	8.25	5.60	45-0	2.80	32-25
Rea quince . . . . .		22.00	36-25	54.00	36-25
Flowering Quince . . . . .	46.25	42.00	45-25	37.60	36-0
Pistacia atlantica . . . . .		16.80	32-25	30.20	36-25

The per cent of germination at the time of collection is given, together with the highest per cent of germination for each of the varieties after 430 days and 550 days of storage. The temperature and humidity conditions under which such germination was obtained is also given.

this that sucrose agar medium enhances and gives more consistent results than sucrose solution for pollen germination after prolonged periods of storage, but a critical study of such differences in culture media would be desirable and of value.

Because of the change in culture media, counts I, II, and III, on the one hand, and counts IV and V, on the other hand, can be considered as two separate groups of data; however, since the tests are still in progress, we are concerned now with the general inter-relation of temperature and humidity to pollen longevity and the actual period of pollen viability. The results, therefore, of only the last two counts (430 and 550 days after collection) are considered here. A more detailed presentation of all of the data will be delayed until the tests are complete. The results of the final counts are indicative of the general trend in reaction of the pollen to storage under varying conditions of temperature and humidity.

After approximately 550 days, all of the pollens germinated under the most favorable storage conditions, and the nature of the tube growth seemed in many cases to be nearly as vigorous as at the time of collection in the spring of 1937. The limited amount of pollen stored at that time did not make it possible to test for actual fertilization of flowers in the orchard during the 1938 period of blossom.

In general, the optimum storage conditions for many of the pollens tested were close to the conditions obtained at 36 degrees F and 25 per cent relative humidity. Rea Quince, Humboldt Nectarine, Thompson's Early apricot, Mingo plum stored best under these conditions. Twenty-five per cent relative humidity was, on the average, definitely the most favorable humidity; however, certain exceptions may be noted in the table, as Belle of Orleans cherry.

The optimum temperature for an average of all the pollens used seemed to lie in the neighborhood of 36 degrees F, although individual pollens varied in this respect. Room temperatures were considerably above the optimum, and resulted in a rapid decrease in the germination percentages. Many of the pollens, however, still showed a few active grains at the last count. Pollens stored at 10 degrees F reacted very similarly to those stored at 0 per cent relative humidity within the favorable temperature range.

The inter-relation of temperature and humidity to pollen longevity stresses the importance of favorable humidity. Twenty-five per cent relative humidity consistently enhanced the storage life of the pollens, even at limiting temperatures, such as room temperature. However, a favorable temperature for any particular pollen is also necessary to secure maximum germination after a long storage period.

On the basis of the first year's records, a second series of tests was begun in the spring of 1938. Only five pollens were selected. They were placed under 12 conditions of humidity (0, 10, 15, 20, 25, 30, 35, 40, 50, 75, 90 per cent, and room) at each of the same four temperatures used in the series of tests reported on here (32, 36, 45 degrees F, and room). Likewise, a sample of each pollen was maintained at 10 degrees F with no humidity regulation. Only two counts have been made to date, but conditions centering around 36 degrees F and 25 per cent relative humidity seem most favorable.

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# Effect of Fruit Thinning on Size, Color, and Yield of Peaches and on Growth and Blossoming of the Tree<sup>1</sup>

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THE relation between the growth and development of fleshy pericarp, stony pericarp, nucellus and integuments, and embryo of the peach have been presented by the senior author (9). At that time it was suggested that the size and development of these parts might offer valuable reference points upon which to base such seasonal operations as thinning, and offer further the advantage of making records from different seasons and for different localities more easily compared. Primarily to test these results the experiment here reported was undertaken.

The plan and technique are similar to those of numerous other experiments on thinning (1, 2, 3, 4, 5, 6, 8) dealing with size and yield of fruit. They differ (a) in the emphasis which is placed upon the time of thinning with reference to stage of development of the fruit rather than upon calendar date, and (b) in the consideration of the effect of regular annual thinning upon number of blossoms, and upon general vigor as exemplified by number and size of leaves.

Because of lack of space, only a summary report is here given. The complete figures of this and other experiments will be combined and presented in a bulletin from the New York State Agricultural Experiment Station.

## MATERIALS AND METHODS

Fourteen 6-year-old Elberta peach trees were used in the experiment, located on the east bank of the Niagara River near Youngstown in western New York. The trees were of good size and vigor and the soil, location, and growing conditions were excellent and typical of the peach growing region of western New York. The tests were conducted during the seasons of 1936, 1937 and 1938. The seasons of 1936 and

TABLE I—STAGE OF DEVELOPMENT AT THINNING

Time of Thinning	Length (Mm)					
	Pericarp		Nucellus and Integuments		Embryo	
	1936	1937	1936	1937	1936	1937
1. Full bloom . . . . .	—	—	—	—	—	—
2. Early stage I . . . . .	23-24	18-19	—	—	—	—
3. End stage I . . . . .	42-45	39-40	6.7	7.5	Microscopic	Microscopic
4. Middle stage II . . . . .	44-46	44	20.5	20.5	Microscopic	1.4
5. Middle stage III . . . . .	50-52	52-55	20.5	20.5	19	19
6. None—check . . . . .	—	—	—	—	—	—

<sup>1</sup>Journal Article No. 322 of the New York State Agricultural Experiment Station.

1937 were good crop years and the season of 1938 was a relatively lighter crop year.

The degree of thinning was determined by estimating the commercial crop which the trees might be expected to carry and then leaving the estimated number of fruits per tree. Although fruits were well separated, no attempt was made to space each fruit uniformly, but rather to adapt the entire load to the estimated capacity of the trees. Records were kept of the number of fruits removed at each thinning, the number of drop fruits, and the number harvested.

The time of thinning in terms of stage of development is shown in Table I and Fig. 1.

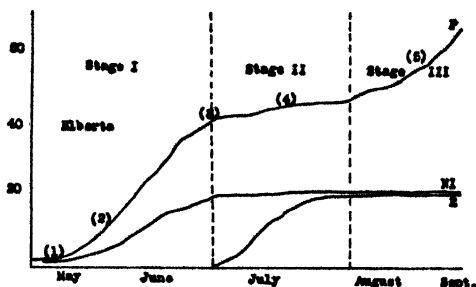


FIG. 1. Development of pericarp (P), nucellus and integuments (NI), and embryo (E) of the Elberta peach from pre-bloom to harvest, showing stages at which thinning operations were performed: 1, full bloom; 2, early stage I; 3, end stage I; 4, middle stage II; 5, middle stage III.

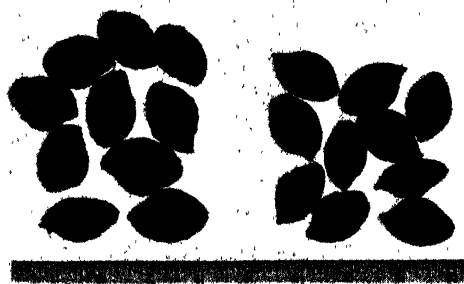


FIG. 2. Early thinning, before the number and size of the cells of the stony pericarp are complete, may affect the size of the stony pericarp as well as the fleshy pericarp. Left, pits from fruit thinned early in stage I; right, from fruit unthinned.

It is interesting to note the variation in dates of thinning during the three seasons. The same stage of development early in stage I as determined by examination of the fruit, the nucellus and integuments, and the embryo was reached June 12 in 1936, June 8 in 1937, and May 26 in 1938. Thinning fruit on the same calendar date in 1938 as in 1936 and 1937 would have resulted in thinning during stage II in 1938 and during stage I in 1936 and 1937.

## RESULTS

*Effect on Flesh and Pit Development:*—Cell division in the fleshy and stony pericarps are completed early in stage I (10) and the size of the stony pericarp is not increased after the completion of stage I. It is to be expected, therefore, that thinning early in stage I might for this reason alone produce different results than thinning at other times. Such was actually the case. In Table II are given the comparison of fleshy pericarp and stony pericarp of fruit from a tree thinned early

TABLE II—EFFECT ON DEVELOPMENT OF STONY AND FLESHY PERICARP DURING STAGE I (1936)

Treatment	Number Fruits per Bushel	Stony Pericarp		Fleshy Pericarp	
		Length (Mm)	Total Weight (Gms)	Total Weight (Gms)	Gain (Per Cent)
Thinned early in Stage I	196	38	1,655	21,514	17.2
Unthinned	209	31	2,058	18,345	—

in stage I and that from a tree not thinned. While the total weight of stony pericarp is greater from the unthinned tree, due largely to the greater number of peaches per bushel, the size of the stony pericarp of individual fruits is greater from the early-thinned trees. Random samples from the two treatments are shown in Fig. 2. It should be noted that early thinning may thus result in larger fruit because of an effect upon the size and development of the stony pericarp as well as upon the fleshy pericarp. The data agree in the principal features with the results of Dorsey and McMunn (1, 4).

*Effect upon Size and Yield of Fruit:*—Thinning in 1936 and in 1937 regardless of time, tended to a reduction in the total yield of fruit as measured in pounds, but to an increase in size and color of individual fruits and increased market value.

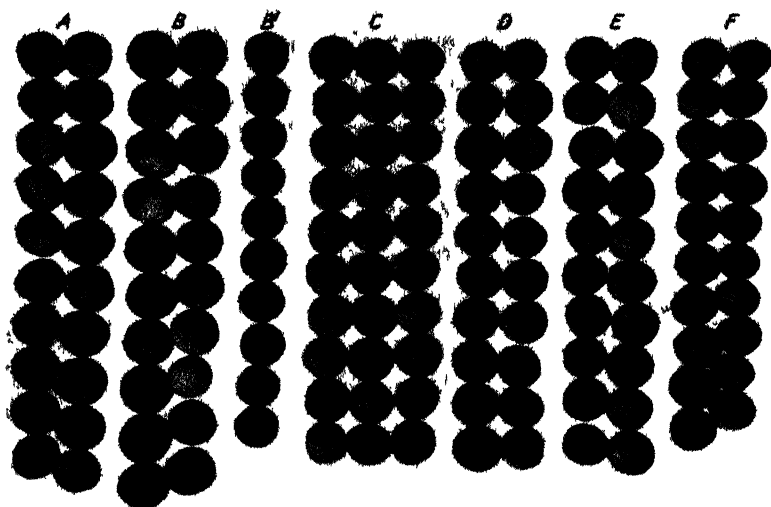


FIG. 3. Random samples of fruit from individual trees in the thinning experiment, showing improvement in size and color from all thinning treatments (A, B, C, D, E) in comparison with no thinning (F); greatest improvement in size and color from thinning at full bloom (A) and early in stage I (B); and intermediate but similar effects from later thinnings (C, D, E), even to shortly before harvest. Results of insufficient thinning (B') even though done early in stage I. Thinning as follows: (A) full bloom; (B) early in stage I; (C) end stage I; (D) middle stage II; (E) middle stage III; (F) no treatment, check.

The most effective time of thinning so far as good size and color of fruit is concerned, coupled with the least reduction in yield, was secured from thinning early in stage I. Blossom thinning, too, was effective but the removal of blossoms without injury to those remaining made the method somewhat uncertain. Thinning at the end of stage I, middle of stage II, or middle of stage III gave results somewhat similar to each other, and which were intermediate between those from no thinning and from thinning early in stage I. The data of Dorsey and McMunn (5) and Farley (6) also show a response from even very late thinning. In Fig. 3 are shown random samples of fruit from the different trees, showing the relation of time of thinning to size and color.

In the light crop year of 1938, however, a much heavier load of fruit was borne on trees that had been thinned early in stage I the two preceding seasons, so that over a 3-year period the total yield as measured in pounds was actually greatest from the trees thinned at that stage. Because of the greater value of the larger yield from thinned trees in the light-crop year, coupled with the improved size and color of fruit in the other two years, the market value of the crop from the early-thinned trees over a 3-year period was much greater than from the unthinned trees. The figures are given in Tables III and IV.

TABLE III—EFFECT ON YIELD OF FRUIT (PER TREE) FOR A 3-YEAR PERIOD

Time of Thinning	1936 (Pounds)	1937 (Pounds)	1938 (Pounds)	Total (Pounds)
1. Full bloom. . . . .	—	167	178	517*
2. Early stage I. . . . .	211	190	306	707
3. End stage I. . . . .	192	149	192	533
4. Middle stage II. . . . .	206	142	77	425
5. Middle stage III. . . . .	187	143	170	500
6. None. . . . .	240	219	122	581

\*Computed on 3-year basis.

TABLE IV—EFFECT ON SIZE OF FRUIT

Time of Thinning	1936 (Inches)	1937 (Inches)	1938 (Inches)
1. Full bloom. . . . .	—	2½ and up	2½ to 2¾
2. Early stage I. . . . .	2½ and up	2½ and up	2½ to 2¾
3. End stage I. . . . .	2 to 2½	2 and up	2½ to 2¾
4. Middle stage II. . . . .	2 to 2½	2½ and up	2½ to 3
5. Middle stage III. . . . .	2 to 2½	Below 2	2½ to 2¾
6. None. . . . .	Under 2	Below 2	2½ to 2¾

*Effect on Fruit Drop:*—The drops were collected during the season of 1937 from June 16 to July 9. The relatively better adherence of the remaining fruits on early-thinned trees, as indicated by the fewer drop fruits, is shown for trees either blossom thinned or thinned early in stage I (Table V).

*Effect on Next Season's Flowering:*—Thinning in 1936 and 1937 markedly affected the total number of blossoms on each tree in 1938. The data, given in Table VI show more than twice as many blossoms per tree, and in some instances three to nearly five times as many on trees thinned either at full bloom or early in stage I. Since the year 1938 was a light-crop year, the differences in bloom were reflected in

TABLE V—EFFECT ON DROPPING OF FRUIT

Treatment	Tree No	June (Stage I)					July (Stage I-II)		Total
		16	19	22	25	28	3	9	
1. Blossom thinned	11	6	19	27	57	31	15	15	170
	12	3	18	21	57	47	10	9	165
2. Early stage I	1	25	16	13	9	20	12	10	105
	2	35	17	7	14	14	7	20	114
3. End stage I	3	21	174	64	113	197	121	120	810
	15	34	212	191	214	57	105	80	893
4. Middle stage II	4	33	252	84	95	211	249	—	924
	5	27	255	129	104	201	210	—	926
	6	5	64	93	81	106	175	—	524
5. Middle stage III	7	4	34	83	105	89	123	55	493
	8	14	56	117	84	170	45	40	526
6. None	9	13	144	61	34	132	100	90	574
	10	19	141	131	193	233	213	70	1,000

the greatly increased yields from these treatments as shown in Table VI. The data agree with the more regular bearing of peach trees as influenced by thinning as reported by Shoemaker (8).

TABLE VI—EFFECT ON NEXT SEASON'S FLOWERING AND ON NUMBER AND WEIGHT OF LEAVES (6TH TO 20TH LEAVES)

Treatment	Tree Number	Number Blossoms per Tree	Dry Weight of Leaf Samples (Grams)	Total Number of Leaves per Tree
1. Blossom thinned	11	2,449	22 40	25,569
	12	2,916	22 10	—
2. Early stage I	1	2,654	21 70	23,919
	2	2,755	23 20	—
3. End stage I	4	960	21 50	14,920
	5	1,050	16 90	—
	6	1,383	18 90	—
4. Middle stage II	7	663	15 50	18,597
	8	422	17 70	—
5. Middle stage III	9	883	14 60	—
	10	1,367	19 00	—
6. None	3	841	19 00	22,931
	15	1,094	18 70	—

*Effect on Total Number of Leaves and Leaf Weight:*—During the season of 1938, trees which had been thinned either at blossom time or early in stage I appeared darker green in color, and the leaves seemed larger. Accordingly from eight branches on each tree the sixth to the twentieth leaves were taken and the oven-dry weight secured, these particular leaves being selected because of their uniformity. During the season of 1937 counts were made of the total number of leaves on trees in four of the six treatments. The data, given in Table VI show both higher number of leaves per tree and a higher dry weight per leaf from the trees thinned either at full bloom or early in stage I.



## CONCLUSION

The stages of development of fruit, nucellus and integuments, and embryo offer more exact reference points for comparison of such operations as thinning in different seasons than do calendar dates.

Thinning at full bloom or early in stage I, before the increase in number and size of cells of the stony pericarp have been completed, has resulted in an increase in the size of the pit. It has also resulted in the largest size and best color of fruit of any of the treatments, and with least reduction in total yield in any one season. Over a 3-year period it has resulted in an increase in number of blossoms in the light-crop year, and in size and number of leaves per tree, resulting in turn in more nearly annual cropping and a greater total yield of fruit for the period as compared with no thinning and thinning at other stages. Thinning early in stage I is more practical than thinning at full bloom.

Thinning at either the end of stage I, middle of stage II, or middle of stage III has given increases in size and color somewhat similar to each other and intermediate between early thinning and no thinning.

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# Abscission of Flowers and Fruits of the Apple

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## ABSTRACT

THE anatomical development of the tissues involved in the abscission process and the mode of abscission of flowers and fruits of certain varieties of apple were studied. Conclusions pertaining to the anatomical aspects of the process were based upon studies of permanent slides and supplementary observations of fresh material. Fresh material was used for all of the microchemical and optical studies which were made in an effort to determine cell wall composition and chemical changes which occurred in the walls of the abscission cells during the course of separation.

The abscission of flowers, and of immature fruits until the completion of the June drop, was preceded by the formation of an abscission layer by secondary cell division. This layer was formed either within the limits of or distal to the abscission zone at the base of the pedicel. Cell separation occurred within the abscission layer and resulted from the breakdown of pectic compounds in the middle lamella and primary wall.

By the time of the completion of the June drop the tissues of the pedicels of growing fruits could be considered to be mature. Maturity was evidenced by the modification of a varying percentage of the pith cells to stone cells, the presence of well-developed stone cells and fibers in the pericycle, very definite bands of secondary phloem and xylem, and the rather extreme thickening, by secondary cellulose lamellae, of the walls of cells of the cortex and of the specialized cells of the abscission zone. The results of microchemical and optical studies showed that the heavy secondary walls of the stone cells of the pith and pericycle were of cellulose, chiefly, lignin in the cell wall being limited to thin lamellae lying in close association with the middle lamella and primary wall and lining the pits and the cell lumen.

Abscission of the mature pedicels (after completion of the June drop) was initiated independently in pith and cortex. In the pith, cell separation was preceded by swelling of the middle lamella and of the secondary wall and elongation of the cells. During this process the walls of the pith cells involved lost the anisotropic quality which indicated a change in the cellulose lamellae. In the course of the separation of the cells, dissolution of the middle lamella and of much of the secondary wall occurred. In tissues other than the pith, there seemed to be less breakdown of the secondary wall accompanying the dissolution of the pectic compounds of the middle lamella. Vessels and fibers in the path of separation were ruptured. Separation in the tissues of the mature pedicel was not preceded by secondary cell division as was noted in connection with the abscission of flowers and immature fruits. Although an abscission zone persisted in the base of the mature pedicel, this zone did not predetermine the path of abscission. Abscission occurred either in the abscission zone or in the pedicel distal to the abscission zone.

In most of the specimens studied, cell separation in the pith preceded the initiation of cortical abscission in McIntosh pedicels. In Golden Delicious pedicels, cortical abscission usually preceded pith separation.

## Annual Bearing in the Wealthy Apple was Induced by Blossom Thinning

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**A**NNUAL fruit production of commercial apple orchards is of marked economic importance to the fruit grower. Young bearing apple trees of many varieties often produce some fruit annually. However, there is a general tendency towards biennial bearing after the trees produce their first very heavy crop. This habit is quite pronounced with such varieties as Baldwin and Wealthy in the East. It is a well established fact that cultural operations such as fertilization, soil management and pruning have not proved to be consistent remedies for such a condition. In other words, climatic factors over a considerable area not infrequently tend to exert a dominating influence in determining the growth status of apple trees.

Excessive blooming and fruit production tend to result in biennial and irregular bearing. Formerly it was quite generally believed that this effect was due in a large measure to the development of a heavy crop of fruit. Well cared for trees in commercial orchards in the on-year, commonly set such large numbers of fruits that thinning is necessary not only to secure fruits of good commercial size and color, but also to prevent severe breakage to the trees.

McCormick (1) states that Yellow Newtown and Ortley apples from the blossoming to the thinning period in 1930 and 1932, carried a load of green apples 300 per cent greater than necessary to produce a full crop.

In thinning a 19-year-old Wealthy tree at New Brunswick having a height and spread of approximately 25 feet in 1935, it was necessary to remove 4,575 fruits which filled 8 bushel baskets and weighed 350 pounds. This illustrates the tremendous waste of carbohydrates which may occur in the period immediately following blooming where the set of fruit is excessive and allowed to develop to the usual time of thinning.

### EXCESSIVE BLOOMING INHIBITS SPRING GROWTH

The fact is now becoming established that even an excessive number of flowers markedly inhibits the leaf development and the total wood growth of the tree in early spring. Theis (2) found that defloration of the McIntosh apple increased the leaf area 41 to 54 per cent by May 25th, 1932. Chandler (3) states that, "the mere formation of many blooms greatly inhibits spring growth". The fact has also been observed many times that when frost destroys the bloom upon a tree in a normal on-year this same tree tends to bloom again the following year.

These facts suggest the question, to what extent does a vigorous bearing tree develop more flowers than are required for annual production? It is obvious that this will vary with the variety, the age and size of the tree and other factors. It raises the further question as to whether all of the flowers developed by a tree are equally dependable

and valuable for production or whether some selection is desirable. Varieties including Baldwin and Wealthy in the East, quite commonly develop spur, terminal and axillary flower buds. Wealthy sometimes produces its first fruits from terminal flower buds. When the trees attain full bearing condition and tend to become biennial, axillary and terminal buds add to the excess formed or set on spurs. It has further been observed that fruit production on the terminals of Baldwin and Wealthy tends to inhibit fruit bud formation on spurs. Speaking of Baldwin in New York, Chandler (4) states, "Sometimes the bloom and the crop will be mainly on the terminal of twigs; much the larger number of spurs being without bloom, yet there will be little or no bloom in the succeeding year". Similar observations have been made upon Baldwin at New Brunswick. Observations of Wealthy show that terminal fruit bearing tends to inhibit fruit bud formation for some distance back of the terminal upon the older wood.

#### STUDIES AT NEW BRUNSWICK

The data later reported in this paper was obtained from 19-year-old Wealthy trees in good vigor, having a height and spread of approximately 25 feet and planted at a density of 50 trees per acre. The annual growth at the tips of vigorous branches was commonly 8 to 10 inches long and relatively thick in diameter; nevertheless, the trees were biennial in bearing habit. In the on-year with a commercial 6 to 8 inch thinning they commonly produced 20 to 25 bushels of apples mostly  $2\frac{3}{4}$  inches and above in diameter. Wealthy trees of this character at New Brunswick differentiate fruit buds profusely upon spurs, terminals and axillaries in the off-year. One such tree in 1935 had a total of approximately 20,000 spurs that bloomed. The number of individual flowers per spur cluster averaged in excess of five. In round numbers, therefore, the tree developed 100,000 flowers, exclusive of terminals and axillaries. A crop of 25 bushels of apples per tree would require a maximum of approximately 2,500 specimens of  $2\frac{1}{2}$  inch apples or 2,000 apples of  $2\frac{3}{4}$  inch size. These figures give some measure of the excess of bloom in an on-year over what is actually required for a crop.

#### CLASSIFICATION OF FRUIT BUDS ON SPURS

Several of the Wealthy trees at New Brunswick possessed an excessive number of dormant fruit buds on spurs in the early spring of 1935. In order to promote annual bearing, plans were formulated for reducing the number of bud clusters prior to full bloom. This brought up the question of the relative quality of the individual spur buds. Previous observations in New Jersey (5) of the Delicious apple had shown that the individual spur buds upon a tree may vary greatly in vigor and ability to set and develop fruit. It was found that they could be grouped in four classes as follows: Class I and Class II comprise large buds which bloom and set fruit well under favorable conditions. Class III is comprised of buds of a slightly smaller diameter than Class II. A percentage of such buds tend to bloom and set fruit but the large majority drop and never mature. Class IV is comprised of buds smaller than those of Class III. A percentage of these may bloom but they will seldom set any fruit that is retained.

Observations upon Wealthy indicated that a somewhat similar relationship existed between individual spur buds of this variety except that a somewhat larger percentage of Class III spurs may set, retain and mature fruit. Since Class III and IV spur buds may bloom but produce little, if any, fruit they largely serve to waste carbohydrates and promote biennial bearing. It, therefore, became apparent in planning the studies to promote annual bearing that the number and distribution of the Class I and II spurs should be made the basis of the studies. Throughout this experiment all well developed dormant spur buds with a minimum diameter of .19 to .21 inches were considered Class II and buds exceeding .22 inches in diameter were regarded as Class I. Examination by sectioning of a considerable number of buds of these two sizes demonstrated that the great majority were differentiated as flower buds. Buds that were not differentiated could usually be detected by their distinct form.

#### DEGREE OF BLOSSOM THINNING

Two blossom thinning treatments in 1935 were based upon distribution of Class I and II buds. Treatment 1, blossom clusters were thinned to a distance apart of 6 to 8 inches. Treatment 2, blossom clusters thinned to 10 to 12 inches apart. All Class III and IV spur flower clusters and all axillary buds were removed. Any terminal buds which were not removed in the dormant season pruning were blossom thinned. Treatment 3 received no blossom thinning but did receive the normal winter pruning given all of the trees which included the removal of terminals and some axillaries. The work of blossom removal was completed as near as possible at the early pink bud stage which was also found to be the most efficient time for their removal. The cluster of buds upon a spur could be quickly pinched off with the thumb and fore-finger of either hand without causing any injury to the newly forming leaves at the base of the developing spur.

#### EARLY RESULTS IN 1935

The effect of blossom thinning in promoting increased leaf development was apparently almost immediate. A second outstanding effect was the increase in the number of fruits set per spur and in the increased rate of growth compared to those upon the tree not blossom thinned. All trees received fruit thinning to one apple per spur. The check tree was thinned so that no two fruits were closer than 6 to 8 inches apart, which amounted to 10 to 12 leaves per fruit. On July 11th, the fruits upon the check tree averaged  $1\frac{3}{4}$  inches in diameter, while those upon the tree blossom thinned to 10 to 12 inches averaged  $2\frac{1}{4}$  inches in diameter.

#### YIELDS 1935

The two blossom thinned trees and the check tree each brought to maturity slightly more than 2,300 apples. A higher percentage, however, of the fruits upon the tree blossom thinned 10 to 12 inches were 3 inches and over in size and this resulted in an increase in yield. Blossom thinning, so that Class I and II spurs were permitted to fruit

6 to 8 inches apart, did not prove to be much different in effect from commercial thinning to 6 to 8 inches. The classified yields are given in Table I.

TABLE I—RESULTS IN YIELDS, 1935 TO 1938 INCLUSIVE

Year and Tree Number	Size Classified in Inches			Total Fruits	Total Yield (Bu)
	2½ and Under	2½ to 3	3 and Over		
1935 1 .....	181	1,347	792	2,320	17.75
2 .....	84	704	1,529	2,317	22.12
3 .....	218	1,729	545	2,492	19.50
1936 1 .....	83	340	196	609	4.87
2 .....	153	1,216	1,341	2,600	26.12
3 .....				none	none
1937 2 .....	31	691	1,572	2,294	23.75
3 .....	23	1,331	830	2,184	20.50
1938 2 .....	34	194	1,214	1,442	17.00
3 .....	17	66	102	185	1.25

Tree 1, blossom thinned to 6 inches.

Tree 2, blossom thinned to 10 to 12 inches.

Tree 3, check, no blossom thinning.

1935 and 1937 normal "on-years".

#### TREATMENT AND RESULTS SECOND YEAR, 1936

During the winter of 1935-36 all trees received a light general pruning wherever there was any crowding, crossing or breakage of branches. The tips of annual growth of all trees were cut back to remove any terminal buds. Since this was the normal off-year for these trees the check tree produced no blossoms. Tree 1 produced only a few blossom clusters and most of these were on one large limb. Tree 2 produced 1,654 spur blossom clusters with an added number of 418 axillary buds which were removed. On June 27th, 1,424 apples were thinned off tree 2, leaving not more than two apples to a cluster.

The yields obtained for 1936 appear in Table I. It is quite apparent that blossom thinning so as to leave Class I and II spurs 6 inches apart did not prove to be sufficient reduction in bloom to insure annual bearing. This treatment was therefore dropped from the experiment after 1936. Blossom thinning so that Class I and II spurs were spaced 10 to 12 inches apart resulted in production of 26.12 bushels of large apples in what would normally be the off-year.

#### STATUS SPRING 1937

Although tree 2 produced a good crop of apples in 1936, it also developed a total of 15,670 fruit buds on spurs. This was considered too large a number for the continuance of annual bearing so 11,281 spurs received the blossom removal treatment and 4,389 Class I and II spurs were allowed to complete blossoming. The check tree developed a heavy set of bloom which was not reduced except in the form of terminal buds removed in dormant pruning.

#### EARLY RESULTS SPRING 1937

This was the on-year for the check, tree 3. In order to compare its relative leaf surface with the blossom thinned tree and another in the

off-year it was necessary to make observations on a third Wealthy tree namely No. 4. The length and width of leaves upon a number of criterion branches of each tree was made the basis for estimating the relative amount of leaf surface of the three trees. These estimates were made in the middle of May. Considering the leaf development upon non-blooming tree 4, as 100 per cent, the regular check, tree 3, had only one-half as much leaf area or 50 per cent, while the blossom thinned tree, number 2, had a leaf area of 75 per cent and enough fruit buds differentiated for a crop in 1938.

#### NUMBER AND DIAMETER OF FRUITS PER SPUR

In order to secure definite data upon the relative set and size of fruits per spur in May 1937, a number of criterion spurs were selected from the blossom thinned tree, number 2, and the on-year tree, number 3, and counts and measurements made. Results are given in Table II.

It is quite clear from the data in Table II that the spurs upon the blossom thinned tree set and retained an average of more fruits per spur than the tree not blossom thinned, and yet the average size of the

TABLE II—AVERAGE DIAMETERS OF GREEN FRUITS AND FRUIT SET (1937)

	Largest Fruit Per Spur		Average All Fruits Per Spur		Number Fruits Set Per Spur	
	Tree 2 (Inches)	Check (Inches)	Tree 2 (Inches)	Check (Inches)	Tree 2	Check
May 27. . .	0.75	0.62	0.66	0.63	5	3
June 8	1.31	1.06	1.25	1.03	3.5	1

fruits in the clusters was greater. These differences were so marked that they were readily noted by the eye. These results agree with the observations made in 1935, the first year of the experiment.

#### YIELDS FOR 1937

The results in Table I show that the check tree produced 20.5 bushels in its on-year, 1937. The bulk of its crop was of a satisfactory size. The reason for this was due to a rather heavy natural thinning. It may be noted that the total number of fruits produced by this tree was 2,184 or a little less than produced by tree 2 which was blossom thinned. The check tree, however, only developed a few scattered Class I and II spur buds for 1938, while tree 2 produced a greater yield of larger apples in 1937 and enough Class I and II fruit buds for a good crop in 1938.

#### 1938 STATUS

In 1938, the check tree was in the off-year. In contrast the blossom thinned tree had enough fruit buds for a crop. There were 2,888 spurs on tree 2 which developed flower buds in the early spring of 1938. These were reduced to 1,743. This reduction was more severe than necessary. It resulted in a yield of only 17.0 bushels which is below the set goal. The apples were exceptionally large in size. It may be

noted in Table I, that, of the 1,442 apples produced in 1938, 1,214 or 84.0 per cent were 3 inches or over in diameter, of these, 415 apples or 28.0 per cent of the total number were 3.5 inches or over in diameter. At this date, December, 1938, tree 2 has enough Class I and II spurs for a crop in 1939.

### SUMMARY

Blossom thinning of a 19-year-old Wealthy tree was begun in 1935. Class I and II spur clusters were thinned at the pink bud stage so that

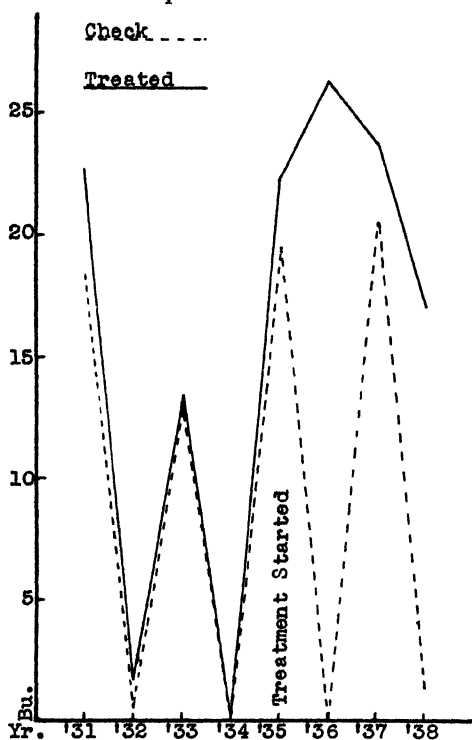


FIG. 1. Yields of check and blossom thinned Wealthy, before and after treatment.

they were distributed 10 to 12 inches apart over the tree. All Class III and IV clusters and all axillary and terminal clusters were removed. The effect was to promote immediately increased leaf development upon all spurs, increase the number of fruit set per spur, and the rate of fruit enlargement. By July 15, 1935, a considerable number of the Class I, II and III spurs deflorated at the pink bud stage, had formed and differentiated flower buds for 1936.

The yield of the check and blossom thinned trees previous to and after treatment are shown in Fig. 1. It may be noted that both trees were biennial in bearing at the time the blossom thinning treatment was started in the spring of 1935.

The maximum number of spurs permitted to bloom annually was approximately 4,500. The maximum number of fruits permitted to develop was approximately 2,600 and the crop goal was 20 to 25 bushels. The majority of the fruits produced on the blossom thinned tree during this 4 year period exceeded 3 inches in diameter. In fact, the 1938 yield records show that 84.0 per cent of the total crop was 3 inches or over in size. This fact together with other indicators supports the conclusion that the blossom thinning in certain seasons was more severe than was necessary to maintain annual bearing, and that somewhat larger yields might have been permitted and annual bearing maintained.



The success of the blossom thinning treatment at New Brunswick is considered to be due to several factors. These include, the growth status of the trees, the removal of terminal flower buds, the removal of Class III and IV flower clusters, the proper number and distribution of the Class I and II clusters allowed to fruit, and some later thinning of the fruits.

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## Further Investigations on the Relation of Pruning to Set of Fruit in Pears<sup>1</sup>

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**E**ARLIER reports (1, 2) showed that pruning of pears increased the percentage of remaining blossoms that set fruit, and that this increased set was more marked for the Anjou than for the Bartlett and Bosc varieties. Subsequently Anjou has been used in studies to determine if possible the physiological cause of the increased set following pruning. Chandler's (4) suggestion that stimulation by pruning might result from increased water or nitrogen supply to the remaining growing points but not from increased carbohydrates was the basis for the further work here reported.

The investigations were conducted in two orchards. In the Medford Experiment Station orchard the Meyer clay adobe soil was fairly well drained. The trees, which had previously received 5 to 7½ pounds of ammonium sulphate per tree and a medium pruning, were moderately vigorous. In the Stratton orchard the Medford fine sandy loam was poorly drained, with a winter and spring water table within 2 to 3 feet of the surface. The trees had never been fertilized, and had previously received only very light pruning. Marked response of nearby trees a year earlier to ammonium sulphate application indicated that these trees were deficient in nitrogen.

In the Medford Experiment Station orchard differential pruning was started in February 1935. Eight trees received no pruning, eight medium pruning, and eight heavy pruning. In the Stratton orchard six trees were given 10 pounds per tree of ammonium sulphate on January 31, 1936. Nine adjacent, slightly more vigorous trees, were left unfertilized. Two fertilized and three unfertilized trees were left unpruned; a similar number were "heavy pruned" on January 31, 1936; and a like number partially deflorated on March 13, 1936, when blossoms were in the "tight cluster" stage.

### PRUNING AND PARTIAL DEFLOURATION IN RELATION TO SET OF FRUIT

The marked effect of dormant pruning in increasing the percentage of blossoms setting fruit is illustrated in Table I. The pruning increased the percentage set sufficiently to more than compensate for the reduction in blossom-buds incident to the pruning, and thus increased the number of fruits per tree. Defloration also resulted in increased set, although the increase was less than resulted from pruning.

### INCREASED SPUR GROWTH FOLLOWING PRUNING

Observations indicated that pruning delayed the opening of the blossoms about 1 day, but increased not only the number of fruits on the remaining spurs, but also the early growth of these fruits. Table I

<sup>1</sup>This is a report of a cooperative project between the United States Department of Agriculture and the Oregon Agricultural Experiment Station.

TABLE I—EFFECT OF DORMANT PRUNING AND OF DEFLOURATION UPON SET OF FRUIT AND UPON DRY WEIGHT (PER SPUR) OF BLOSSOM CLUSTER, PEDUNCLE, AND SMALL FRUIT

Location and Treatment	Blossom Clusters Remaining After Pruning Ex- pressed as Percentage of Blossom-Buds Before Pruning (Per Cent)	Blossoms Setting and Holding Fruit (Per Cent)	Dry Weight Per Spur		
			Blossoms Beginning to Open (Milli- gram)	Just after Petal Fall	
				Peduncle (Milli- gram)	Small Fruit (Milli- gram)
Medford Experiment Station Orchard (1935)					
No pruning . . . . .	100	0.9 ± .08	246.2	40.7	30.6
Medium pruning . . . . .	90	2.1 ± .12	261.4	44.7	35.4
Heavy pruning . . . . .	70	3.0 ± .12	260.2*	46.9	37.8
Stratton Orchard (1936) No Ammonium Sulphate					
No pruning . . . . .	100	1.4 ± .09	218.9	39.6	67.8
Defoliation . . . . .	50	2.6 ± .31	242.5	44.7	—
Heavy pruning . . . . .	50	4.9 ± .47	239.8	48.4	84.2
Stratton Orchard (1936) 10 Pounds Ammonium Sulphate Per Tree					
No pruning . . . . .	100	1.6 ± .08	233.9	45.7	70.0
Defoliation . . . . .	50	2.9 ± .33	254.1	52.8	—
Heavy pruning . . . . .	50	5.3 ± .18	217.2	54.9	88.1

\*One of duplicate samples lost.

shows that, with the exception of the low figure for dry matter for "blossoms beginning to open" for heavy pruned-fertilized trees in 1936, due perhaps to initially low vigor of these two trees, pruning, and also partial defloration, was followed by increased dry weight (per spur) of the blossoms just before full bloom and of the peduncles and small fruits immediately after petal fall. Thus, pruning resulted in increased growth, as measured by total dry matter, per blossoming point.

#### CARBOHYDRATES

Just before full bloom, the total sugars and the total acid-hydrolyzable polysaccharides including starch, hereafter termed "reserve carbohydrates", expressed as percentage of dry matter, (see Table II) were slightly but consistently lower for pruned and deflorated than for non-pruned trees. However, the data expressed as absolute amounts per spur indicate that the pruning did not greatly affect the total amount of carbohydrates per spur at the time of sampling.

#### NITROGEN IN MODERATELY VIGOROUS TREES

The alcohol soluble nitrogen expressed as percentage of dry matter (Table III) in the peduncles and small fruits was reduced following pruning in the Medford Experiment Station orchard. This decrease apparently began before full bloom.

The absolute amount of nitrogen per spur in pruned trees was only from 0.9 to 2.2 per cent higher in the tight cluster stage, and only from 4.0 to 4.3 per cent higher just before full bloom. After full bloom, absolute amount of nitrogen was 6.9 and 13.2 per cent higher for the peduncles and small fruits, respectively, following medium pruning;

TABLE II—EFFECT OF DORMANT PRUNING AND OF DEFLOURATION UPON CARBOHYDRATE CONTENT OF BLOSSOM CLUSTERS JUST BEFORE FULL BLOOM\*

Location and Treatment	Carbohydrates			
	Percentage of Dry Weight		Absolute Amounts per Cluster	
	Total Sugars (Per Cent)	Reserve Carbo-hydrates (Per Cent)	Total Sugars (Milligram)	Reserve Carbo-hydrates (Milligram)
<i>Medford Experiment Station Orchard</i>				
No pruning . . . . .	8.63	17.39	21.25	42.81
Medium pruning . . . . .	8.44	17.21	22.06	44.99
Heavy pruning . . . . .	8.24	17.23	21.44	44.83
<i>Stratton Orchard, No Ammonium Sulphate</i>				
No pruning . . . . .	11.39	16.76	24.93	36.69
Defloration . . . . .	11.06	16.65	26.82	40.38
Heavy pruning . . . . .	10.96	16.65	26.26	39.93
<i>Stratton Orchard, 10 Pounds Ammonium Sulphate</i>				
No pruning . . . . .	10.53	17.10	24.63	40.00
Defloration . . . . .	10.39	16.81	26.40	42.71
Heavy pruning . . . . .	10.21	16.87	22.18	36.64

\*Samples collected: Medford Experiment Station, April 11, 1935, Stratton Orchard, April 1, 1936.

and 2.1 per cent lower and 15.7 per cent higher for peduncles and small fruits, respectively, following heavy pruning. Thus for these moderately-vigorous trees, only in the case of the small fruits was the total nitrogen per spur increased following pruning.

#### NITROGEN IN NITROGEN DEFICIENT TREES

In the Stratton orchard the application of 10 pounds of ammonium sulphate per tree on January 31 was followed by a slight increase in the percentage of total nitrogen in the blossoms (Table IV) by April 1

TABLE III—EFFECT OF DORMANT PRUNING UPON PERCENTAGE NITROGEN IN DEVELOPING BLOSSOMS, PEDUNCLES, AND SMALL FRUITS ON MODERATELY VIGOROUS TREES IN 1935

Material and Date of Sampling		Nitrogen Content, as Percentage of Dry Weight		
		No Pruning (Per Cent)	Medium Pruning (Per Cent)	Heavy Pruning (Per Cent)
Tight blossom clusters (March 28) . . . . .	Soluble	.50	.60	.58
	Insoluble	2.76	2.71	2.77
	Total	3.35	3.31	3.35
Blossoms starting to open (April 11) . . . . .	Soluble	.91	.80	.79
	Insoluble	2.98	3.01	3.05
	Total	3.89	3.81	3.84
Just after petal fall (April 25) Peduncles . . . . .	Soluble	1.78	1.55	1.15
	Insoluble	2.85	2.94	2.77
	Total	4.63	4.49	3.92
Small fruits . . . . .	Soluble	1.15	.98	.92
	Insoluble	2.82	2.90	2.77
	Total	3.97	3.86	3.69

just before full bloom; and by a large increase in the peduncles by April 18, just after petal fall. However, this increase in percentage nitrogen following ammonium sulphate application was not accompanied by a significant increase in set of fruit (see Table I). The defloration and pruning did result in increased percentage of blossoms setting fruit; but the percentage nitrogen increased only in the case of unfertilized trees, and then only to a slight extent just before full bloom and just after petal fall. Hence the set of fruit did not show any relation to nitrogen expressed as percentage of dry matter.

TABLE IV.—EFFECT OF AMMONIUM SULPHATE, DEFLOURATION, AND DORMANT PRUNING UPON PERCENTAGE NITROGEN IN DEVELOPING BLOSSOMS AND SMALL FRUITS OF NITROGEN DEFICIENT TREES IN 1936

Material and Date of Sampling		Nitrogen Content, as Percentage of Dry Weight					
		No Ammonium Sulphate			10 Pounds Ammonium Sulphate		
		No Pruning (Per Cent)	Deflor- ation on March 13 (Per Cent)	Heavy Pruning on January 31 (Per Cent)	No Pruning (Per Cent)	Deflor- ation on March 13 (Per Cent)	Heavy Pruning on January 31 (Per Cent)
Blossom-buds (January 31)	Soluble	.07	.07	.08	.08	.08	.07
	Insoluble	.96	.95	.99	1.01	1.01	1.01
	Total	1.03	1.02	1.07	1.09	1.09	1.08
Tight blossom clusters (March 13)	Soluble	.67	.58	.68	.64	.64	.60
	Insoluble	2.61	2.72	2.54	2.74	2.66	2.85
	Total	3.28	3.30	3.22	3.38	3.30	3.45
Just previous to blossom opening (April 1)	Soluble	.68	.72	.75	.78	.74	.73
	Insoluble	2.36	2.45	2.41	2.51	2.56	2.56
	Total	3.04	3.17	3.16	3.29	3.30	3.29
Just after petal fall (April 18) Peduncles	Soluble	1.88	1.83	1.98	2.29	2.06	2.15
	Insoluble	2.40	2.52	2.48	2.67	2.64	2.60
	Total	4.28	4.35	4.46	4.96	4.70	4.75
Small fruits	Soluble	1.37	—	1.37	1.71	—	1.34
	Insoluble	2.85	—	2.81	3.27	—	3.03
	Total	4.22	—	4.18	4.98	—	4.37

The fertilized, but not the unfertilized trees, showed the reduction in percentage nitrogen in peduncles and small fruits as a result of pruning, observed for moderately vigorous trees in 1935.

The absolute amount of total nitrogen per peduncle after full bloom seemed to have been increased (Table V) by defloration and by pruning in fertilized as well as unfertilized trees. However, the increase in total nitrogen per peduncle was only about half as great for the fertilized as for the unfertilized trees, while the set of fruit was increased, by defloration or by pruning, as much in the fertilized as in the unfertilized trees.

#### WATER

Over a period of several years the daily period of stomatal opening was frequently, but not always, found to be about 1 hour longer for heavily pruned than for unpruned trees. However, the percentage water in blossom samples taken for analysis (Table VI) was not

found to be consistently higher for the pruned than for the unpruned trees. Leaf samples taken in the Medford Experiment Station plots during full bloom in 1936 showed no difference in percentage water in the morning, but did show a lesser decrease in water content during the day for the pruned trees. Water injected into one scaffold limb of each of 10 medium pruned trees at this time (15 liters taken up in about 36 hours) did not affect the set of fruit. Injections of asparagin (.084 grams per liter) and of dextrose (3.75 grams per liter) also showed no effect on set.

TABLE V—EFFECT OF DORMANT PRUNING AND OF DEFOLIATION UPON TOTAL DRY WEIGHT AND TOTAL NITROGEN PER SPUR FOR BLOSSOMS BEFORE FULL BLOOM AND FOR PEDUNCLES AND SMALL FRUITS JUST AFTER PETAL FALL (STRATTON ORCHARD, 1936)

Stage of Development	Type of Material Collected		No Ammonium Sulphate			10 Pounds Ammonium Sulphate per Tree		
			No Pruning (Milli-gram)	Deflor-ation (Milli-gram)	Heavy Pruning (Milli-gram)	No Pruning (Milli-gram)	Deflor-ation (Milli-gram)	Heavy Pruning (Milli-gram)
Tight blossom clusters (March 13) . . . . .	Entire cluster	Dry weight	111.3	97.9	92.6	87.6	88.2	83.3
		Total nitrogen	3.65	3.23	2.98	2.96	2.91	2.87
Just previous to blossom opening (April 1) . . . . .	Entire cluster	Dry weight	218.9	242.5	239.8	233.9	254.1	217.2
		Total nitrogen	6.65	7.69	7.58	7.70	8.39	7.15
Just after petal fall (April 18) . . . . .	Peduncle	Dry weight	39.6	44.7	48.4	45.7	52.8	54.9
		Total nitrogen	1.70	1.95	2.16	2.27	2.48	2.61
	One small fruit per spur	Dry weight	67.8	—	84.2	70.0	—	88.1
		Total nitrogen	2.86	—	3.52	3.49	—	3.85

TABLE VI—EFFECT OF DORMANT PRUNING UPON PERCENTAGE OF WATER IN DEVELOPING BLOSSOMS AND IN SMALL LEAVES OF MODERATELY VIGOROUS TREES (1935 AND 1936)

Material and Date of Sampling	Water Content, as Percentage of Fresh Weight		
	No Pruning (Per Cent)	Medium Pruning (Per Cent)	Heavy Pruning (Per Cent)
Tight blossom cluster (March 28, 1935) . . .	75.5	75.2	75.4
Blossoms starting to open (April 11, 1935) . . .	79.4	79.0	79.1
Just after petal fall (April 25, 1935)			
Peduncles . . . . .	74.0	75.3	74.6
Small fruits . . . . .	78.0	78.0	77.5
Small leaves during 9:30 to 10:30 a.m. . . . .	75.3 74.8	75.3 75.3	74.9 75.3
full bloom 4:00 to 5:00 p.m. . . . .	73.9 73.8	74.2 74.2	74.3 74.5
(April 14, 1936) Decrease . . . . .	1.4 1.0	1.1 1.1	0.6 0.8

In 1937 three trees, which had received medium dormant pruning each February from 1933 to 1937, were heavily pruned in late March 1937, by removing the distal third of all limbs. This removed about 4 years growth. Three adjacent trees, also medium pruned in February 1937, were used as "checks". The percentage of blossoms setting fruit

on the terminal 3 feet of representative limbs was 2.7 per cent for check, and 3.9 for cut-back trees. During petal fall (April 27), and subsequently during May, the daily period of stomatal opening was greater, while the decrease in water content during the day was less, for spur leaves on the cut-back than on the check trees. Thus increased set of fruit following pruning was associated with increased water supply to the leaves, and presumably, to blossoms.

### DISCUSSION

The increased percentage of blossoms setting fruit following partial defloration suggests that the increased set following dormant pruning may have been partially due to the reduction in number of blossoms, which during their development undoubtedly drew upon the reserves of necessary substances, particularly carbohydrates and nitrogen. The lesser stimulation by defloration than by pruning might have been due both to the 6 weeks later removal of blossom parts, and to the lack of removal of wood and of leaf buds, by defloration.

The stimulatory action of dormant pruning of Anjou not only greatly increased the percentage of blossoms setting fruit, but also increased the size of the peduncle and developing fruit. If this stimulation of set and growth were due to an increased supply of carbohydrates or nitrogen to the remaining spurs, the increased supply would be distributed throughout the new growth. In such a case, although the percentage of carbohydrates or nitrogen in the new growth might not be increased or might be reduced, the total amount per spur should show an increase.

The data show no appreciable increase in either total sugars or reserve carbohydrates expressed as absolute amounts per spur. Therefore, the only increase in carbohydrates associated with the increased set was the amount used in the formation of the increased amount of cellulose, which constitutes a large portion of the increased dry matter per spur, and whatever amount was used in the respiration of the increased amount of new growth. The total amount of nitrogen per spur, however, was increased, possibly before full bloom, and certainly by petal fall, as a result of both defloration and pruning. However, since the ammonium sulphate fertilization of the nitrogen deficient trees resulted in approximately as great an increase in nitrogen supply to the blossoms as the defloration and pruning, but did not cause the same increase in set, it would seem that the increased nitrogen per spur following defloration or pruning was not the causal factor in the increased set.

The longer daily period of stomatal opening and the smaller decrease in water content of the leaves during or just following full bloom in response to pruning corresponds to the greater stomatal opening and increased fruit growth following leaf removal in early summer, reported for Anjou by Aldrich and Work (3). In both cases reducing the transpiring area in proportion to the temporarily unaffected root area increased the water supply to the leaves. That this should occur in the spring when average available soil moisture is usually above 50 per cent of the available capacity indicates that, in spite of high soil

moisture, the rate of water intake by the roots was not sufficient to prevent water deficits in the leaves.

However, there is still no definite evidence that increased water supply to the blossoms following pruning caused the increased set of fruit. The possibility should be kept in mind that the increased set following pruning might be due to effects of increased respiration near the cuts, or to activation of enzymes or growth promoting substances.

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# The Effect of Size of Young Pecan Trees on Their Subsequent Growth and Yield

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THE results from a fertilizer experiment<sup>1</sup> on pecan trees showed a very wide fluctuation in individual tree yields and to a lesser extent in tree growth. Although there were significant differences in the plot means, the variations in tree yields and growth were so great as to preclude any definite conclusions regarding the relative value of the treatments. Since the size of the young trees at the time the experiment began varied considerably, it seemed advisable to determine what relation this variation might have to the yields and growth which followed.

## EXPERIMENTAL MATERIALS

The experiment was inaugurated in the spring of 1926 to determine the quantity of nitrogen in a complete fertilizer, applied annually, that would give the best results in tree growth and yield. For this experiment three single row plots, of 23 trees each of 5-year-old Schley pecan trees, separated by guard rows, were selected in an orchard in the vicinity of Albany, Georgia. Since the trees began to show effects of crowding in 1935 the even numbered trees in each row were cut out in the spring of 1936, leaving 12 trees for each treatment. Yield records and trunk circumference measurements from which cross-sectional areas could be calculated were made annually from 1926 through 1937. From these data, the size of the trees at the time the experiment was initiated in terms of trunk cross-sectional area, the growth in terms of total increase in cross-sectional area for the 12 years, and the accumulated yield in pounds for the same period has been determined for each tree.

## STATISTICAL METHODS

The data for this paper have been taken from the records of those trees remaining after thinning. All of the methods used in analyzing the data have been taken from Snedecor's "Statistical Methods" (1). Analyses of variance were first made for both the total increases in trunk cross-sectional area and the accumulated yields. Co-variance analyses were then made for initial size (size of the trees at the time the experiment was initiated) and growth, and for initial size and yield. From the co-variance analyses, the regression and correlation coefficients for initial size and growth and for initial size and yield were calculated. Using the regression coefficients, the yield and growth of the individual trees were adjusted to their initial size.

In order to show the effect of adjustment on each treatment, mean differences in the original or unadjusted growth and yields and their significances were determined between plots A and B, B and C, and

<sup>1</sup>This is a cooperative experiment conducted by the Division of Soil Fertility and the Division of Fruit and Vegetable Crops and Diseases of the Bureau of Plant Industry.

A and C. The same procedure was then repeated using the adjusted growth and yields.

### PRESENTATION OF DATA

The adjustment of growth to initial size brought about a rather small reduction in the growth variation between the trees. The variation in growth expressed by the range in total increase in cross-sectional area in square inches has been reduced in plot A from 42.3 to 35.5, in plot B from 45.1 to 35.8, and in plot C from 69.1 to 66.6. The reduction in the error sum of squares for the whole experiment due to the regression of initial size on growth is but a very small part of the error sum of squares, as is shown in Table I. The non-significant correlation coefficient and the comparatively small regression coefficient (Table II) give further evidence that the effect of initial size on growth is of minor importance.

The adjustment of tree yields brought about by the regression of initial size on yield has altered the individual tree yields in such a way as to reduce the variation between trees by about one-half. The variation as indicated by range in pounds per tree has been reduced from 88.0 to 63.9 in plot A, from 94.0 to 46.1 in plot B, and from 103.0 to 94.4 in plot C. The regression of initial size on yield accounts for over half the error sum of squares. In other words, over half of the heretofore unexplained variation in tree yields is due to the variation in the size of the trees at the start of the experiment. In fact, the treatments themselves have produced a variation in tree yields which is less than half that due to the variation of the initial size of the trees (Table I). The reduction in the error sum of squares due to regression

TABLE I—ANALYSIS OF VARIANCE OF SOURCES OF VARIATION

Source of Variation	Degrees of Freedom	Growth		Yield	
		Sum of Squares	Mean Square	Sum of Squares	Mean Square
Total . . . . .	35	9,777.5	—	29,472	—
Treatments . . . . .	2	1,635.0	817.5*	4,021	2010.5*
Block† . . . . .	1	847.8	847.8	7,715	7715**
Error‡ . . . . .	32	7,294.7	228.0	17,360	542.5
Reduction of error due to regression . . . . .	1	806.6	806.6	9,379	9,379**

†Due to a difference in soil type and a difference in cultural treatment during the early years of the experiment between the north and south half of the rows, the sum of squares due to block difference is accounted for.

‡Error refers to that sum of squares unaccounted for by either block or treatment differences.

§Sum of squares of deviations from the mean.

\*Significant.

\*\*Highly significant.

is highly significant as is shown in Table I. The importance of initial tree size in determining the subsequent yield is brought out again by the highly significant correlation and the very large regression coefficient between initial size and yield.

Unfortunately, the trees in plot A were considerably smaller than those in plots B and C at the start of the experiment, as is shown in Table III. Because of this difference in the average initial size of the

TABLE II—CORRELATION AND REGRESSION COEFFICIENTS

	Correlation Coefficients				Regression Coefficients
	Plot A	Plot B	Plot C	Whole Experiment	Whole Experiment
Initial size and growth ..	.305	.511	.401	.3325	2.5133
Initial size and yield...	.693*	.872**	.676*	.7272**	8.5779

\*Significant.

\*\*Highly significant.

trees in the three plots there is a reduction in the mean differences in both the adjusted growth and adjusted yield between plot A and the other two plots. The reduction in the mean difference in growth between plots A and C, and in yield between plots A and B have resulted in a change from significance to non-significance, the value of "t" at the 5 per cent level of significance being 2.074 for 22 degrees of freedom. The adjustment of yield has reduced the mean differences between the plots much more than has the adjustment of growth. However, the adjustment of yield has also reduced the standard errors much more than has the adjustment of growth, and has therefore lowered the values of "t" to no greater extent.

Since there was but little difference in initial size as well as yield and growth between plots B and C, a comparison of these two plots does not appear in Table III. The adjustment of both growth and yield has, however, given greater values of "t" because of a reduction in the standard error.

TABLE III—MEAN DIFFERENCES AND THEIR SIGNIFICANCE IN UNADJUSTED AND ADJUSTED GROWTH AND UNADJUSTED AND ADJUSTED YIELD

Variable	Plot	Average* Initial Size	Mean**	Mean Difference	Sum of Squares	Pooled† Variance	Standard Error	"t"
Unadjusted growth..	A	3.69	69.8	7.9	1393.5	156.1	5.1	1.550
	B	5.27	77.7	—	2041.25	—	—	—
Adjusted growth..	A	—	72.3	4.0	1322.5	130.2	4.66	0.858
	B	—	76.3	—	1541.6	—	—	—
Unadjusted growth..	A	3.69	69.8	16.6	1393.5	275.8	6.78	2.448†
	C	5.20	86.4	—	4674.9	—	—	—
Adjusted growth...	A	—	72.3	12.8	1322.5	246.5	6.41	1.996
	C	—	85.1	—	4097.0	—	—	—
Unadjusted yield....	A	3.69	87.3	22.2	8018	653.6	10.44	2.126†
	B	5.27	109.5	—	6351	—	—	—
Adjusted yield . . .	A	—	95.9	8.8	4301	272.4	6.72	1.310
	B	—	104.7	—	1692	—	—	—
Unadjusted yield....	A	3.69	87.3	22.5	8018	871.8	12.05	1.867
	C	5.20	109.8	—	11162	—	—	—
Adjusted yield . . . .	A	—	95.9	9.7	4301	490.3	8.98	1.080
	C	—	105.6	—	6435	—	—	—

\*Average size of trees (at the time the experiment was started) expressed as trunk cross-sectional area in square inches.

\*\*Average total increase in square inches in trunk cross-sectional area per tree for growth. Average accumulated yield in pounds per tree for yield.

†Total sum of squares of two plots/number of degrees of freedom.

‡Significant.

## DISCUSSION

A very wide variation in size of the trees existed at the time the experimental treatments were initiated, although the trees used in the experiment were the same age and variety and had received the same fertilizer and cultural treatment prior to that time. This variation could have been due to differences in size of the trees at planting, care and technique in planting, variation in the soil, the genetic makeup of the understock, or some other factor.

Normally it would not be expected that this early history of the trees should have such a dominating effect on yield and not on growth. This may be explained from the fact that trees of the Schley variety in many cases fail to mature a crop of nuts although they had a normal bloom; and this has often been true in this experiment. Since some of the trees have matured a larger crop than others, and apparently it has been those trees which had the largest initial size, the seasonal growth of those trees would be somewhat retarded. On the same basis, the growth of those trees maturing the smallest crops, which were those having the smallest initial size, would be somewhat less retarded. This relationship between fruiting and growth would therefore tend to mask the effect of the initial size on the subsequent growth of the trees. It is highly possible that with other soil and climatic conditions, or with other pecan varieties, the initial size would produce as great an effect on growth as it has on yield in this experiment.

## CONCLUSION

The analysis of co-variance has altered the significance of the experimental data to such an extent that an interpretation of the data without the analysis of co-variance would be very much in error. This analysis has shown a much closer relationship between initial size and yield than between initial size and growth. In fact, the relationship between the initial size and yield is so close as to make possible the planning of an experiment of this type, even where trees of uniform size cannot be obtained.

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# Three Years Results of Thinning the Stand as Compared with Pruning Thickly Planted Pecan Trees

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## INTRODUCTION

**I**N the average pecan orchard the trees are planted about 50 by 50 feet on squares, or closer. Under such conditions the trees begin to crowd after 15 to 20 years, at which time they need more space. In native groves the trees usually stand very close together and in thinning the stands the usual practice is to leave the trees even closer than in the planted orchard. The pecan tree grows naturally to a very large size which is undesirable from the standpoint of orchard management because of the increased difficulties in spraying, pruning, and harvesting operations. However, most pecan trees are allowed to grow naturally and they utilize an increasing amount of space with increase in age. Consequently, the trees are crowded to various degrees in most of the older planted orchards and native or topworked groves.

It is not desirable from an economic standpoint to space trees so far apart that they will not eventually reach a crowded condition because the yield per acre will be low while the trees are small, and the cost of caring for the trees will be too great in proportion to the income from the orchard. However, most growers are reluctant to thin the stand of trees when they need it, due mainly to sentimental reasons, and to some extent to lack of knowledge as to when thinning needs to be done. Pelham (6) and Woodroof (7) have shown that the normal root spread of a pecan tree is about twice that of the branch spread. Thus, the roots begin to crowd long before the branches are touching and thinning in some manner is needed at the time this condition is reached.

The number of trees per acre may be reduced by thinning the stand, or the size of the trees may be reduced by pruning. Crane (1), and later Crane and Hardy (2), found that pruning by thinning out branches and opening up the tops of older bearing pecan trees at Albany, Georgia stimulated shoot growth of the trees and materially increased the size of the individual nuts and increased the degree of filling slightly, but had no influence on total production. However, on 10-year-old Schley trees, Crane and Dodge (3) found that pruning stimulated growth so that an increased number of strong fruiting shoots were produced and thereby the set of nuts was increased. Crane, Hardy, Loomis, and Dodge (4) found that thinning the stand of 24-year-old Stuart pecan trees from 20 to 10 trees per acre increased the size and filling of the nuts. Hardy and Lutz (5) later reported on this same block of trees and showed that the average yield per acre for the 4 years 1933 to 1936 was 132.0 pounds compared with 130.5 pounds for the control trees in an unthinned block. The nuts from the thinned block were larger and better filled than those from the controls, which indicates that the trees originally were crowded. The same authors (4, 5) reported on 24-year-old Stuart trees that stood 46 feet 8 inches

on the square system and which had the tops cut back to about half their size in 1932, with subsequent light or corrective pruning and some heading back of long branches. These trees produced only 49.9 pounds of nuts per acre for the period 1932 to 1936 because of the severe heading back. Field observations in Texas have shown that severe heading throws pecan trees into a vegetative condition, and the more severe the heading the longer the time required to regain bearing condition. There may also be varietal differences in the responses to heading back. However, it is likely that severe pruning such as the above mentioned trees received would throw any variety out of bearing for at least several years, whereas more moderate pruning might have the opposite effect.

Since relatively small trees are desirable for orchard use; since it is desirable to have a large number of trees per acre in young pecan orchards to increase the yields per acre while the trees are small, and since the average grower is reluctant to thin the stand of trees, it seemed desirable to obtain some information on the effects of moderate dwarfing of crowded trees by pruning as compared with thinning the stand of trees.

#### METHODS OF PROCEDURE

Two blocks of comparable 12-year-old trees of the Burkett variety were selected in the grove of Ross Wolfe at Stephenville, Texas. These trees were standing approximately 27 feet apart on the square system. The soil is a sandy loam of fairly low fertility. The trees in one block, consisting of three rows of 8 trees each, were pruned on March 8, 1935.



FIG 1 A typical tree of the Texas Prolific variety at the beginning of the experiment, March 8, 1935

The outside branches were cut back so as to reduce the size of the top by about one-fifth of its original size. The branches that were cut back were relatively small, being in most cases less than 1 inch in diameter and usually less than 2 or 3 feet in length. The pruning was repeated in March, 1936, and in February, 1937, cutting the tops back each year to approximately the same size as in 1935. In the second block the stand was reduced to seven trees 45 by 45 feet on squares and the trees were not pruned.

Two blocks of trees of the Texas Prolific va-

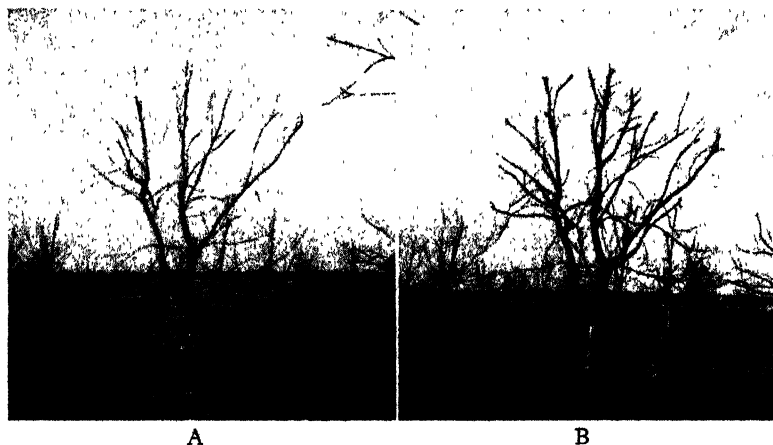


FIG. 2. A typical pruned tree of the Texas Prolific variety. A, after pruning in March, 1935; B, after pruning in February, 1937.

riety were given the same treatments as the Burkett variety. The pruned block consisted of 18 trees that stood approximately 18 by 18 feet on squares while the unpruned block consisted of 10 trees that stood approximately 30 by 40 feet on rectangles. Most of the pruned trees of this variety were smaller than those not pruned. A typical tree at the beginning of the experiment is shown in Fig. 1, while a typical tree after pruning in 1935 and in 1937 is shown in Fig. 2.

Records of trunk growth, yields, cost of pruning, nut quality, degree of filling, and size of nuts, as well as general tree conditions, were made each year and these data are presented in Tables I to III.

TABLE I—THE AVERAGE YIELDS OF PECAN NUTS PER ACRE ON PRUNED TREES AND ON UNPRUNED, THINNED TREES

Variety	Number Trees per Acre		Average Yield per Acre		Increase per Acre on Pruned Trees (Pounds)
	Pruned	Unpruned	Pruned Trees (Pounds)	Unpruned Trees (Pounds)	
1935					
Burkett .....	59.7	21.5	1212 ± 71*	673 ± 69	530 ± 99
Texas prolific.....	134.4	36.3	1304 ± 152	904 ± 94	400 ± 179
1936					
Burkett .....	59.7	21.5	258 ± 24	7 ± 6	251 ± 25
Texas prolific.....	134.4	36.3	297 ± 31	94 ± 15	203 ± 34
1937					
Burkett.....	59.7	21.5	1012 ± 65	608 ± 105	404 ± 123
Texas prolific.....	134.4	36.3	1198 ± 99	401 ± 55	797 ± 113

\*Standard error.

TABLE II—PERCENTAGE OF KERNEL, NUMBER OF NUTS PER POUND, AND THE VOLUME OF NUTS FROM PRUNED AND FROM UNPRUNED, THINNED TREES (1935 TO 1937)

Variety	Treatment	Average Percentage of Kernel*	Average Number of Nuts per Pound	Average Volume per Nut (Cc)
1935				
Burkett	Pruned trees	56.3	61.7	9.28
Burkett	Unpruned, thinned trees	53.1	66.0	9.42
Texas prolific	Pruned trees	52.8	76.0	7.73
Texas prolific	Unpruned, thinned trees	53.8	69.0	8.39
1936				
Burkett	Pruned trees	57.5	49.7	10.86
Burkett	Unpruned, thinned trees	58.3	43.5	11.21
Texas prolific	Pruned trees	55.18	56.2	9.49
Texas prolific	Unpruned, thinned trees	54.78	51.7	10.08
1937				
Burkett	Pruned trees	57.97	48.45	11.20
Burkett	Unpruned, thinned trees	57.14	46.80	11.58
Texas prolific	Pruned trees	55.30	55.05	9.53
Texas prolific	Unpruned, thinned trees	54.25	50.95	10.24

\* Weight of kernel  
Weight of whole nut = percentage of kernel.

## RESULTS AND DISCUSSION

*Yields of Nuts:*—The yields of nuts for the 3 years were calculated on the acre basis and are given in Table I. In the good crop year of 1935 the unpruned, thinned trees of the Burkett variety produced about half as many nuts per acre as pruned trees, while the production from unpruned, thinned Texas Prolific trees was about two-thirds as much per acre as from the pruned trees. The average yield per tree was greater for unpruned, thinned trees of each variety but the number of pruned trees per acre was much greater. The Burkett nuts from pruned trees were of better quality than nuts from unpruned, thinned trees, as is indicated by the percentage of kernel, Table II. However, the actual differences in nut quality are not all given by the differences in percentage of kernel. About 25 per cent of the nuts on unpruned Burkett trees germinated before harvest time while no germination of nuts occurred on pruned trees. The foliage on pruned trees remained on the trees in good condition until after the nuts were harvested, while about 50 to 60 per cent of the foliage of unpruned, thinned trees had dropped before the date of nut harvest.

With the plentiful supply of soil moisture in 1935, and the reduced leaf area on unpruned trees, the nuts probably were subjected to a very high concentration of water, which was conducive to sprouting, whereas the large number of leaves on the pruned trees were able to rid the nuts of excessive moisture by transpiration. There was no sprouting of nuts on any of the Texas Prolific trees, and there was less difference in the amount and condition of the foliage of pruned and unpruned trees than in the Burkett variety. The nuts of the Texas Prolific variety are generally less likely to germinate on the tree than those of the Burkett variety under such conditions.



In 1936, a light crop year, the yield of nuts on unpruned, thinned Burkett trees was extremely low, whereas on pruned trees the crop was large enough to be profitable. The unpruned, thinned Texas Prolific trees yielded 94 pounds of nuts per acre, as compared with 7 pounds for similar trees of the Burkett variety, but the actual increase in per acre yield for the pruned trees was 203 and 251 pounds for the two varieties respectively. The great increase in the yield of pruned Burkett trees was no doubt due largely to the better condition of their foliage in the fall of 1935. With the foliage remaining in good condition on the trees until after the nuts were harvested sufficient carbohydrates were assimilated to fill the nuts as well as to furnish storage reserves for the trees. Thus the trees were able to blossom and set a fair crop of nuts in the spring of 1936, whereas the unpruned, thinned trees which lost a large part of their foliage previous to nut maturity in 1935 were sufficiently depleted of storage carbohydrates to prevent much blossoming the following spring. In the Texas Prolific variety the yield per tree of unpruned, thinned trees was only slightly higher than that of the pruned trees, while in the previous year these trees yielded almost three times as many pounds of nuts per tree. Therefore, the difference in the foliage conditions, even though not so great as in the Burkett, must have been responsible for the better relative yield of the pruned trees in 1936. The relative yields in both varieties show that the differences in yield per acre are not due entirely to the reduction in number of trees because the unpruned, thinned trees were larger in 1936 than they were the previous year.

Pruned trees of both the Burkett and the Texas Prolific varieties retained their foliage in good condition until frost in 1936, while unpruned Burkett trees lost 50 per cent or more of their leaves before the date of nut harvest, and the unpruned Texas Prolific trees lost about 20 per cent of their leaves prior to nut harvest.

In 1937, a fair crop year, the acre-yields were higher from the pruned trees of both varieties. All trees in the experiment were sprayed for control of downy spot in the spring of 1937, and as a consequence the foliage remained on all trees until after the nuts were harvested. In the two previous years, trees in the pruned blocks had held their foliage, but the unpruned, thinned trees had lost a great deal of their foliage during the nut filling period. The downy spot fungus was less severe on the foliage of pruned trees, apparently because of the increased vigor of the foliage as compared with that of the unpruned, thinned trees. The average yields per acre for each variety were greater each year from closely planted pruned trees than from unpruned, thinned trees and these increases in yield are statistically significant as is shown by the standard errors, Table I.

*Quality and Size of Nuts:*—Except for the Burkett variety in 1935, there was little difference in the percentages of kernel of the nuts produced by trees of the same variety in the two treatments (Table II). The nuts from pruned Burkett trees in 1935 contained 56.3 per cent kernel and only 61.7 nuts were required to weigh 1 pound, whereas nuts from unpruned, thinned trees contained 53.1 per cent kernel and 66 nuts weighed 1 pound. The reverse was true of the nuts from the

Texas Prolific variety. Nuts from pruned trees were lower in percentage of kernel and the average weight per nut was less than for nuts from the unpruned, thinned trees. In 1936 nuts from pruned trees of the Burkett variety had 57.5 per cent kernel as compared with 58.3 per cent for nuts from unpruned, thinned trees, and the number of nuts per pound was greater from pruned trees. In the Texas Prolific variety the percentage of kernel was higher and the number of nuts per pound was greater in nuts from the pruned trees. In 1937, the nuts from pruned trees of both varieties contained a little higher percentage of kernel but were smaller than nuts from unpruned, thinned trees. The data in Table II show that the average volume per nut from unpruned, thinned trees of each variety was larger in each year than that of nuts from pruned trees, and the odds (calculated by Student's method) are 587 to 1 that the differences are significant. The average weight per nut, as shown by the number per pound, was also greater for nuts of each variety from unpruned, thinned trees each year except for the Burkett in 1935, but odds (Student) of 9 to 1 show that the differences are not significant.

*Market Value of Nuts Produced per Acre:*—In Table III is given the market value per acre of the nuts produced from trees in the two treatments. These are on the basis of prices received by the grower and are the average prices received by all growers for comparable nuts in those years. It is noted that the income per acre was greater from the pruned trees of both varieties than from the unpruned, thinned trees. The increased income per acre for the three years was \$183.56 for the

TABLE III—MARKET VALUE OF NUTS PRODUCED PER ACRE BY PRUNED TREES AND BY UNPRUNED, THINNED TREES (1935 to 1937)

Year	Value of Nuts Per Pound (Cents)	Market Value of Nuts Produced Per Acre		Increased Value of Nuts Per Acre from Pruned Trees
		Pruned Trees	Unpruned Thinned Trees	
<i>Burkett Variety</i>				
1935	12	\$145.44	\$ 80.76*	\$ 64.68
1936	20	51.60	1.40	50.20
1937	17	172.04	103.36	68.68
Total		\$369.08	\$185.52	\$183.56
<i>Texas Prolific Variety</i>				
1935	12	\$156.48	\$108.48	\$ 48.00
1936	20	59.40	18.80	40.60
1937	15	179.70	60.15	119.55
Total		\$395.58	\$187.43	\$208.15

\*No deduction has been made for the nuts that germinated on these trees in 1935, which was approximately 25 per cent of the yield.

Burkett variety and \$208.15 for the Texas Prolific variety. Perhaps the greatest significance from the standpoint of income from pruned trees is the showing in 1936 when the crop was profitable from pruned trees while from unpruned, thinned trees the yield would not have paid for the care of the orchard in the case of the Burkett variety, and profits would have been negligible from the Texas Prolific variety.

The yields of the pruned trees were much lower in 1936 than in the other 2 years but the price of the nuts was higher due to the small crop. Nevertheless at the price of 10 or 12 cents per pound there would still have been a profit from the pruned trees.

*Cost of Pruning the Trees:*—The average cost of pruning was about 6 cents per tree the first year and 4 cents per tree each year thereafter. This is based on a labor charge of \$2.00 per day, for which it was possible to obtain a competent man to do the pruning. The cost of disposing of the brush from pruned trees has not been included in the cost of pruning since this will vary with local conditions.

*Growth of the Trees:*—The pruned trees made less trunk growth than the unpruned, thinned trees, and no doubt less top growth as well. This is what would be expected since the tops of unpruned trees were much larger than those of pruned trees. Previous observations have shown that trunk growth of pecan trees is somewhat proportional to the size of top. This observation is borne out in the present study, since the unpruned trees had much larger tops than pruned trees. The leaf area per unit of trunk cross-section was greater in unpruned trees, but the leaf area per nut was less in years when there was a fair to good crop.

#### CONCLUSION

A comparative study has been made of the effects of moderate dwarfing by pruning and of thinning the stand of 12-year-old pecan trees of the Burkett and Texas Prolific varieties.

The average yield of nuts per acre for the 3-year period from pruned trees was about twice as great as from unpruned, thinned trees and the total income per acre was proportional to the yields. The average yield per tree was greater from the unpruned, thinned trees each year except for the Burkett variety in 1936.

The foliage of pruned trees remained in normal condition on the trees until late in the season each year, whereas a considerable portion of the leaves of the unpruned, thinned trees dropped prematurely, except in 1937 when the trees were sprayed with Bordeaux mixture to control leaf diseases. In this year there was no apparent difference in foliage conditions on the pruned and unpruned Burkett trees, but the foliage of the pruned Texas Prolific trees was held on the trees later and was in better condition than the foliage of unpruned, thinned trees.

During the fall of 1935 about 25 per cent of the nuts on unpruned, thinned Burkett trees germinated just prior to harvest time. About 50 to 60 per cent of the leaves on these trees dropped prematurely during the nut filling period, whereas no leaves dropped from the pruned trees and no sprouting of nuts occurred. Also, the nuts from pruned trees of this variety were better filled than nuts from the unpruned, thinned trees.

Due to the stimulation of tree growth by the pruning, the pruned trees had more foliage per nut in years of fair to good crops, and apparently were able to fill the nuts and also store sufficient carbohydrates in the trees to cause a set of nuts the following year. Such a condition tends to eliminate alternate bearing, which is so common in the pecan.

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# Intraclass Correlation for Horticultural Research

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**I**NTERCLASS correlation is commonly in use. It consists in a determination of the degree of concomitant variation between classes of entities that are separable, and separated, because of clear-cut distinctions, and yet are, in some manner, sympathetically related.

At times, it is both desirable and profitable to learn as well the degree of similarity in character of the individuals of one and the same class. Techniques for so doing, when the groups of measurements segregatable within an entire class are designated as, say, fraternities, have been affected and rendered available for use.

Such correlations, when obtained, are known as intraclass coefficients. The data having been gathered in groups of equal size, these coefficients express the variation of the group means relative to the variation within the groups. In other words, they show the extent to which the individuals of a group, which tend to be alike and constitute a fraternity, differ from those of the other groups, within the same general class.

The pairs in intraclass correlation differ from those accomplished in interclass correlation inasmuch as they are "twin measurements without order". Each pair specifies two points in the dot diagram or two entries in the correlation table. With " $n$ " measurements in each group, the number of pairings and consequent entries is  $n(n-1)$ . The total of the entries is  $m[n(n-1)]$ , " $m$ " being the number of groups. Obviously, when the number of groups is large, the task of forming and handling the pairs becomes too great for convenience and accuracy. The same is true when the groups chance to be few but the number of measurements per group is large.

Effort to reduce this difficulty, notably that of J. Arthur Harris (2, 3, 4), has been successfully made. A review of his papers yields a knowledge of his inventions. Moreover, it gives complete information on the theory of intraclass correlation and also on the earlier methods for its derivation. At the best, however, the technique, in most cases, was overly laborious, and unduly susceptible to errors in calculation.

The recent biometrical procedure, termed "analysis of variance", has the general merit of greater simplicity of computation. Its use is possible for intraclass correlations (1). Correlation is essentially but the ratio of two measures of variation. The numerator of the ratio states the variance common to both variates; the denominator the average of the two separate variances. This relation exists alike for both intraclass and interclass correlation. The method supplied in the "analysis of variance" obviates the necessity for the formation and the tabulation of the pairs of measurements and consequently is more feasible and rapid. A demonstration is offered in the following computation: Counts of the number of normal berries per bunch were made (in August) for 25 bunches, taken at random, on each of 40 grapevines of the Concord variety. The vines, rooted in a single soil type, were of

the same age; had had the same cultural treatment in the past, and showed apparent uniformity of vigor.

Taken together, they constitute a general class. Each vine, with its 25 observations may be designated as a sub-class, or better, a fraternity. What, if any, is the correlation between the pairs of samples, for size of bunch, from the same vine? The required tabulation, in abbreviated form, appears in Table I.

The next step is the familiar process of the analysis of variance. Table II gives the form of computation.

TABLE I—NUMBER OF BERRIES PER BUNCH FOR CONCORD GRAPE

Bundles	Vines												40	Total																																																																													
	1	2	3	4	5	6	7	8	9	10	11																																																																																
1	42	28	20	33	28	46	47	36	36	47	48	36																																																																															
2	53	36	70	55	37	47	49	51	50	24	41	23																																																																															
3	26	35	35	45	36	38	23	31	30	36	62	15																																																																															
4	46	34	28	41	25	40	32	59	26	25	63	31																																																																															
5	44	25	46	44	57	51	42	60	50	34	48	27																																																																															
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<table><tr><td>3</td><td>-12</td><td>-19</td><td>-10</td><td>-9</td><td>4</td><td>-1</td><td>-5</td><td>-1</td><td>12</td><td>2</td><td></td><td>4</td></tr><tr><td>14</td><td>-4</td><td>31</td><td>12</td><td>0</td><td>5</td><td>1</td><td>10</td><td>13</td><td>-11</td><td>-5</td><td></td><td>-9</td></tr><tr><td>-13</td><td>-5</td><td>-4</td><td>2</td><td>-1</td><td>-4</td><td>-25</td><td>-10</td><td>-7</td><td>1</td><td>16</td><td></td><td>-17</td></tr><tr><td>7</td><td>-6</td><td>-11</td><td>-2</td><td>-12</td><td>-2</td><td>-16</td><td>18</td><td>-11</td><td>-10</td><td>17</td><td></td><td>-1</td></tr><tr><td>5</td><td>-15</td><td>7</td><td>1</td><td>20</td><td>9</td><td>-6</td><td>19</td><td>13</td><td>-1</td><td>2</td><td></td><td>-14</td></tr><tr><td>14</td><td>9</td><td>-4</td><td>3</td><td>10</td><td>-2</td><td>8</td><td>-11</td><td>2</td><td>8</td><td>9</td><td></td><td>10</td></tr></table>														3	-12	-19	-10	-9	4	-1	-5	-1	12	2		4	14	-4	31	12	0	5	1	10	13	-11	-5		-9	-13	-5	-4	2	-1	-4	-25	-10	-7	1	16		-17	7	-6	-11	-2	-12	-2	-16	18	-11	-10	17		-1	5	-15	7	1	20	9	-6	19	13	-1	2		-14	14	9	-4	3	10	-2	8	-11	2	8	9		10
3	-12	-19	-10	-9	4	-1	-5	-1	12	2		4																																																																															
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2051 2877 3513 4563 2229 2456 2984 3447 1820 3882 4778   2248  125,505																																																																																											

TABLE II—ANALYSIS OF VARIANCE OF BERRIES PER BUNCH WITH CONCORD GRAPE

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Individual items within the groups. ....	980	125,505	130.73
Vines. ....	39	25,904	664.23
Totals. ....	999	151,409	

Two estimates of population variance are included in Table II, one (130.73) for the individual bunches within the groups, and the other (664.23) based upon the vine means. The significance of the greater variation, derived from fewer degrees of freedom, can now be tested.

After Fisher, the sample ratio (F) is equal to the larger variation over the smaller. Hence,

$$F = 664.23 / 130.73 = 5.1$$

This sample value (5.1) far exceeds both the 1 and 5 per cent points of the table for the distribution of F. Therefore, the vines differed

significantly among themselves. The numbers of berries per bunch were the consequence of local influences and varied from vine to vine. Was this variation concomitant, and if so, to what degree?

As to formula, intraclass correlation is the simple ratio:  $A/A + B$ . The character  $B$  is the mean square within the groups (130.73 for these data);  $A$  symbolizes the random variation associated with the vines.

The actual variance of the vine means is not  $A$  but is equivalent to  $A + B/25$ , since 25 is the number of counts per vine. The *mean square* between vines is  $k$  times this variance,  $k$  being 25 in this instance. Hence, mean square =  $25 (A + B/25) = 25 A + B$ . It follows that  $25 A + B = 664.23$ , and that with  $B = 130.73$ ,  $A = 21.34$ .

Obviously,  $A$  is equal to  $\frac{V_b - V_w}{k}$ , where  $V_b$  and  $V_w$  represent the mean squares between and within the groups and  $k$  is the number of items per group. Using this relationship which, in a way, is more expressive, the formula for intraclass correlation can be written as  $\frac{V_b - V_w}{V_b + (k-1)V_w}$ .

Substituting the proper values for  $A$  and  $B$  in the ratio  $A/A + B$  and solving, intraclass correlation is found to be 0.141.

The range of the values of " $r$ " in intraclass correlation is not from  $-1$  to  $+1$ , as in interclass correlation, but from  $-1/(k-1)$  to  $+1$ , with  $k$  the number of items in each group. Here, therefore, the range is from  $-0.042$  to  $+1$ .

The coefficient (0.141) is positive. It is also low. The  $F$ -test, applicable to intraclass correlation, shows it to be significant. Correlation obtained between the pairs of samples from the same vine. This relationship, however, appears too weak to indicate an organic factor of great force and major importance. It is permissible to infer that with respect to the set of berries in the bunches, and more especially as to their subsequent retention and development, each bunch followed its course mostly independently. The physiological ministry of the vine was, for the most part, to bunches individually rather than as interdependent members of a closely coordinated whole.

Cross intraclass correlations are possible, and often valuable to obtain. Suppose counts of the numbers of flowers per cluster had been made, at time of blossoming, on these same vines and clusters, and the intraclass coefficient computed for these measurements! Correlation as between flowers and berries could then be derived through use of a formula supplied by Harris (4):

$$r_{f,b} = \frac{S\{\sum(f')\sum(b') - S(f')(b')\} / S[n(n-1)] - \bar{f}\bar{b}}{\sigma f \sigma b}$$

The symbols  $f$  and  $b$  are for flowers and berries respectively. The rest is plain in meaning. The numerator gives the variance common to both variates, the denominator the average of the two separate variances. The quotient, of course, is simply an interclass correlation or so-called coefficient of correlation. It has, however, the distinction of being based upon two intraclass procedures, with their greatly increased pairings,

and therefore, is of considerably greater accuracy and significance than if obtained in the usual manner for interclass correlation.

The present is an epoch of statistical emphasis and necessity. The need and desire for mathematical procedures to sharpen the attack upon and broaden the solution of the problems confronting investigators in the plant sciences is everywhere felt. Intraclass correlation, where not already in use, appears as a possibility for gaining a particular and essential type of information. Its adoption in horticultural research may be urged especially, since in this field so many aims and cultural practices involve some kind of conception with respect to organic unity of structure, function, and response in the plant forms under treatment and observation.

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## Maturity Studies with Jonathan and Grimes Golden Apples<sup>1</sup>

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THE studies reported in this paper were started in 1934 in an effort to determine the nature of the physical and chemical changes of maturing apples under Maryland conditions, and if possible to thereby arrive at reliable indices of maturity in relation to the proper time for harvesting Grimes and Jonathan apples.

### MATERIALS AND METHODS

In Table I data concerning varieties, number of trees used for testing, indices tried and other information for the 4 years of the experiment have been condensed.

In 1934 and 1935 the fruit was graded into three size groups before storing: (a) under 2½ inches, (b) 2¼–2½ inches, and (c) over 2½ inches, referred to as small, medium, and large size groups respectively. The fruit from each tree was kept separate throughout, and the counts of the number of fruits falling into each size group made it possible to estimate the average fruit size for each tree, and to calculate weighted average values for the various physical and chemical determinations. With certain exceptions three lots of 20 fruits each were then selected from each size group from each tree. These samples were placed in open bags in storage, and were used for chemical samples. One sample was used immediately, and one at each of two storage periods. The physical determinations were made on lots of 20 fruits selected from the remainder of the fruit from each size lot from each tree.

Twenty fruits from each size group from each tree served as samples for tests with a Magness and Taylor (8) pressure tester, an electrical maturity tester similar to that described by Moore (9), and ground color estimates on the Grimes variety with a Magness and Diehl (7) color chart. Red color on the Jonathan variety was estimated as per cent of the surface of the fruit covered with red color. The pressure test and electrical maturity test were taken at three points around the circumference of each fruit, and the 60 readings thus obtained were averaged. The average was considered as the test of the sample. The skin was removed for the pressure test, but not for the electrical maturity test.

Total solids, reducing substances, sucrose, total sugars, starch, and total nitrogen were the chemical fractions determined. All except the starch analyses were made by the usual methods. The starch analyses were made after the method of Denny (4), in an effort to determine the absolute quantities present as accurately as possible.

In 1936 experiments with the electric maturity tester were attempted to duplicate actual commercial conditions. From every test tree in each

<sup>1</sup>Scientific Contribution No. 487, Department of Horticulture, Maryland Agricultural Experiment Station.

TABLE I.—DATA CONCERNING VARIETY, TREE, SOIL TREATMENT AND SAMPLING METHODS FOR MATURITY DURING 4 YEARS OF INVESTIGATION

Year	Variety	Number Trees in Experiment	Age of Trees	Number Pickings or Storage Samples	Size of* Sample Per Tree (Bushels)	Indices Used	Soil Type, Cultural Conditions Orchard data
1934	Grimes	36	13	6, Starting August 23	2	Ground color, Pressure test, Chemical analysis, Electrical maturity tester	Penn. gravelly loam near Frederick, 5 pounds NaNO <sub>3</sub> per tree yearly; weed sod.
	Jonathan	36	22	6, Starting August 27	2	Ground color, Pressure test, Chemical analysis, Electrical maturity tester, Per cent bluish	Penn. gravelly loam near Frederick, 5 pounds NaNO <sub>3</sub> per tree yearly; weed sod.
1935	Grimes	25	13	5, Starting August 24	2†	Same as in 1934	Fertile Upshur loam, near Colesville; 6 pounds NaNO <sub>3</sub> yearly; weed sod; fruit dropped badly after third picking.
	Jonathan	25	13	5, Starting August 29	2†	Same as in 1934	Same as in 1934, but from a younger planting; fruit dropped badly after fourth picking.
1936	Grimes	20	Varied	4, Starting August 25	½	Electrical maturity tester	12 different commercial orchards mostly in Washington County. Commercial conditions sought.
	Jonathan	16	Varied	4, Starting August 25	½	Electrical maturity tester	12 different commercial orchards mostly in Washington County. Commercial conditions sought.
1937	Grimes 1	2	15	3, Starting August 29	½	Starch-iodine reaction, Index number	From same block used in 1934.
	2	2	15	3, Starting August 29	½		From same block used in 1935.
	3	3	Varied	7, Starting August 24	½		Sassafras loam at College Park; 5 pounds NaNO <sub>3</sub> yearly; Bluegrass sod stimulated complete fertilizer in 1928.
	Jonathan 1	2	24	3, Starting August 29	½	Starch-iodine reaction, Index number, Per cent bluish	From same block used in 1934.
	2	2	15	3, Starting August 29	½		From block adjoining Grimes block used in 1935. Same conditions as in Grimes block.
	3	2	15	6, Starting August 24	½		Block adjoins Grimes block 3. All conditions identical.

\*All selected trees bore sufficiently heavy crops to furnish fruits for all storage and test samples.  
†6th picking a random sample of 4 bushels from several trees.

orchard test samples were taken every 2 days and storage samples once weekly. Twenty fruits were used for testing on each sampling date, and for the weekly storage samples approximately  $\frac{1}{2}$  bushel was picked at random from each tree.

To study the daily variations in the readings of the electric maturity tester, fruits of summer varieties were brought to constant temperatures in 1937 before testing. The temperatures used were 55 degrees F, room temperature,  $75 \pm 10$  degrees F and 90 degrees F. Fifteen fruits were tested soon after picking on each test date, and 15 fruits were exposed to each of the three temperatures for 6 hours before testing.

Of the 50 fruits selected for the semi-weekly tests in 1937, 15 were selected at random for the "index number" test (5). The fruits were placed in a freezing temperature of approximately 7 degrees F. They remained at this temperature overnight, and then were allowed to thaw. One-quarter of each fruit was used to obtain the final amount of juice by extraction with a hydraulic press. The juice was strained and centrifuged until clear. With a few cubic centimeters of the juice pH measurements were taken with a Beckman pH meter. For the acid determinations three titrations of 10 cubic centimeters each were made with .0528 N sodium hydroxide using phenothalein as an indicator. The average of the three titrations was used as the titratable acidity of any one sample.

Ten of the 50 fruits were used for a starch-iodine reaction test (3). The fruits were halved and dipped in iodine solution, 0.25 grams iodine and 1 gram potassium iodide to 100 cubic centimeters of water, for 1 minute. After removal they were allowed to dry 5 minutes and compare with a starch-iodine reaction chart (3). The average of the 10 apples determined the starch content of the sample on any picking date.

The percentage of blush was estimated on 25 fruits selected at random from the weekly storage samples.

The storage samples were handled in a similar manner all 4 years. After harvesting fruit at the various picking dates it was removed immediately to College Park, Maryland, and placed in storage. The storage temperature was 32 degrees F with a humidity of 80 to 85 per cent.

Palatability tests in December served as the true standards of maturity and storage quality in 1934 and 1935. In 1936 and 1937 the fruits were graded in January, and in 1937 graded again after the fruits had been removed from cold storage to a 60 degrees F storage room for 5 weeks. Grad-

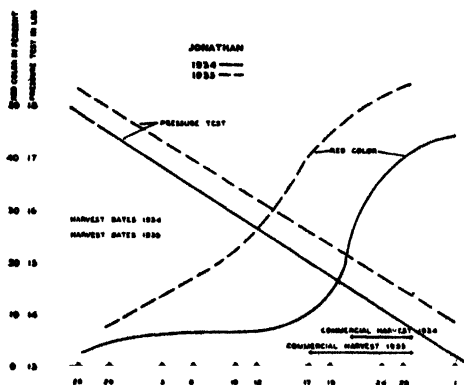


FIG. 1. Average change in pressure test and development of red color for Jonathan apples at weekly harvest intervals in 1934 and 1935.

ing methods consisted of throwing out all scalded, rotted and wilted fruit. In addition palatability tests were made on representative fruits from storage in January.

### RESULTS

As indicated in Fig. 1, the estimate daily decrease in pressure test was too slight to afford an adequate index of fruit maturity, and even on a weekly basis the differences were only barely significant. An inverse relationship between fruit size and pressure test was evident throughout the harvest periods.

A preliminary report (6) on the application of the electrical maturity tester to Grimes and Jonathan showed a seasonal trend which might be used as an index of maturity. However, the results of these experiments indicated certain undetermined factors affect readings so materially that the slight shift in readings during the critical period is without significance. In Fig. 2 are presented the electric maturity curves

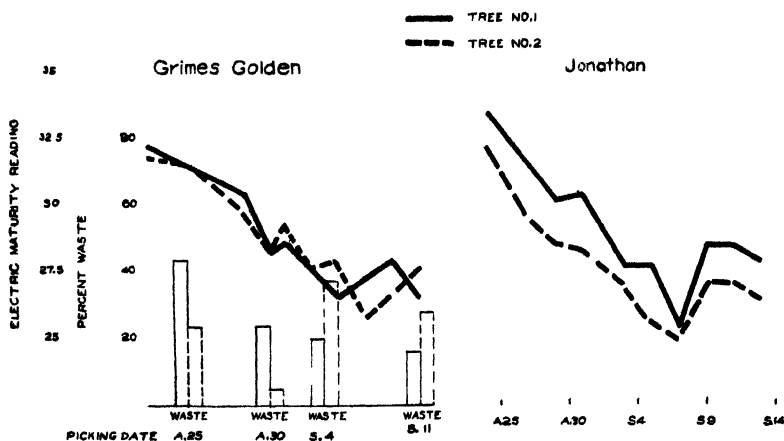


FIG. 2. Changes in readings of the Electrical Maturity Tester on representative samples of Grimes and Jonathan trees and per cent wastage in January of storage samples of Grimes, 1936.

from two Grimes and two Jonathan trees in one of the test orchards of 1936. The presented curves are generally representative of those obtained in other orchards. A downward trend with maturity was pronounced, but variations in the curve descent were apparent. The decided similarity of the curves from all trees of the same orchard or region indicated unisolated factors, other than maturity of the fruits, were influencing the individual readings to a large extent. Attempts to control this variation by exposing the fruits to controlled temperatures before testing led to the conclusions that changes in readings on fruits at controlled temperatures from just prior to maturity until proper picking time were too small to be of great significance. Analysis of variance for dates did not always show a bare 5 per cent significance.

The results with ground color studies with Grimes clearly indicated that in moderately vigorous orchards, under Maryland conditions, the

ground color may remain fairly constant during the maturation period, and would never reach the recommended value on the Magness and Diehl color charts until after the fruit fell from the trees, as it did in 1935.

Red color estimates on random samples of Jonathan fruit showed distinctly different trends in 1934 and 1935 as shown in Fig. 1. The data indicate these differences were due to sunlight and temperature relationships. Although the curves of color development differed in 1934 and 1935, palatability tests showed that those storage samples which had developed more than 25 per cent red color before picking developed the best cold storage quality. The 1937 results (Figs. 3 and 4) show that 40 per cent red color was necessary before Jonathan developed best edible quality. Since the 1934 and 1935 estimations were made by the senior author and the 1937 estimations were made by the junior author, it is probable that individuality in judgment accounted for part of the discrepancy in estimating the per cent red color. In 1937 blush seemed no index in forecasting the development of storage disorders. Thus a comparison of Figs. 3 and 4 show that the samples of Fig. 3 developed greater wastage than those of Fig. 4, but there were no differences in percentage of blush.

While the analyses for the trends in the sugar content during the matu-

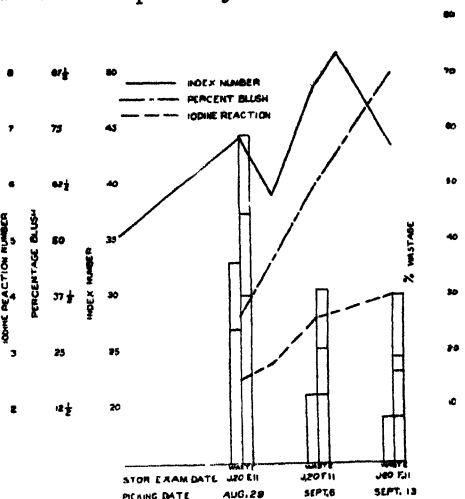


FIG. 3. Index number, per cent blush and iodine-starch reaction number and per cent wastage on January 20 and February 11 for samples of Jonathan tree No. 1 at the test and harvest dates, 1937.

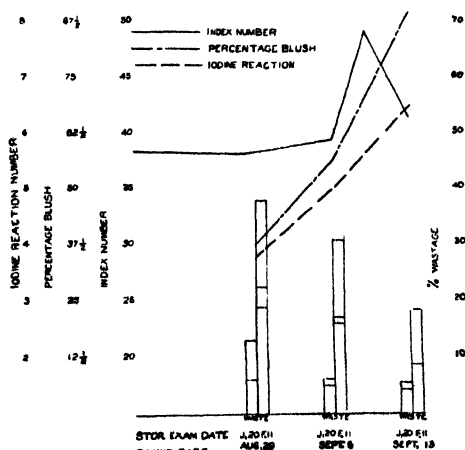


FIG. 4. Index number, per cent blush and iodine-starch reaction number and per cent wastage on January 20 and February 11 for samples of Jonathan tree No. 2 at the test and harvest dates, 1937.

ration period are of interest, there was no apparent correlation between the changes noted and fruit maturity. The trends, in general, reflect those found by Askew (1), Bigelow, *et al.* (3), and others. The sucrose content of both varieties showed a definite trend during the harvest period, but was not closely correlated with picking maturity.

Because the reducing sugar values were relatively constant for both varieties during the maturation period, the total sugar values closely reflect the sucrose content of the fruit at any given picking date.

The starch values are of interest, and are shown in Fig. 5. In 1935 the Grimes variety showed a decrease from around 7 per cent starch at the first harvest to about 2 per cent at the fifth harvest date. The

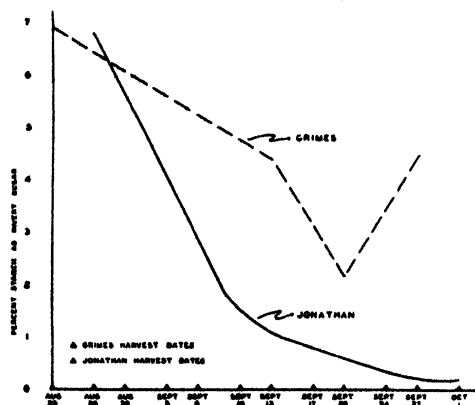


FIG. 5. Average per cent starch of Grimes and Jonathan apples at weekly harvest intervals, 1934.

last picking showed an increase to about 4 per cent. The reason for this increase is not known. It is interesting to note that the sucrose content of the Grimes variety showed a decrease of nearly 10 per cent in this same weekly interval. Although the data gave no evidence as to the factors controlling this starch increase of the last sampling, Plagg, Maney and Gerhardt (10) suggested a similar increase in starch percentage of Grimes might be due to growth resumption caused by excessive rains following a dry period. In the Jonathan variety the initial starch content was about the same as for the Grimes variety. However, in this variety the decrease at the successive weekly intervals was much more pronounced, and by the fourth picking the starch content of the Jonathan fruit had fallen to below 1 per cent, and to approximately 0.25 per cent at the end of the sixth week. On a qualitative basis, as used in 1937, there was insufficient change in Grimes prior to harvest to be used as a maturity index. Normal flavor development in Grimes was not largely dependent upon the stage of maturity at harvest. On Jonathan, however, a qualitative test of six, based on the starch-iodine chart of M. B. Davis (3), was reached before best storage quality obtained.

Although the 1937 data indicated a possible correlation between starch test and percentage of blush, experiments in 1938 showed no such correlations. Using the qualitative starch test on three sampling dates, "Students" method revealed that apples covered with black bags August 5 to prevent color formation were not differing significantly in starch content from the closest adjoining uncovered fruits.

"Index number" curves of the fruit of two typical Jonathan trees are presented in Figs. 3 and 4. The "index number" test seemed to have

no applicability to Grimes and Jonathan in Maryland in 1937. Although all curves reached a maximum before the best harvest period, as measured by storage quality, the variations of the samples made any interpretation extremely difficult. In order to accurately rely upon any index indicative of proper time of harvest, there must be some clearly defined change or the index must reach a predetermined point to prevent false conclusions. During the critical period the curves of the "index numbers" did not show differences incapable of misinterpretation. Inconclusive data suggested that size of fruit might play a role in determining the "index number".

In general none of the indices tried have proven wholly successful in forecasting maturity. Chemical analyses revealed that starch loss might be correlated with maturity of Jonathan. This view was substantiated by results with the starch-iodine reaction test. The development of red color on Jonathan before harvest indicated correlation with palatability upon removal from storage, but proved of no value in determining storage waste.

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## Seasonal Changes in the Ascorbic Acid Content of Juice of Florida Oranges<sup>1</sup>

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THIS investigation was made to obtain information on the changes which take place in the leading commercial varieties of Florida oranges during their development and ripening on the tree. The findings reported herein are based on a systematic study involving the completion of several thousand tests made periodically from 1935 to 1938. The detailed data in this report however are for the seasons of 1936-37 and 1937-38 only, since the work done in 1935-36 was largely of a preliminary nature.

The studies made included the following measurements: weight of fruit, diameter of fruit, thickness of rind, color of flesh and juice, volume of juice, flavor, total acids, total water-soluble solids, and ascorbic acid (vitamin C). In the present paper only the results on ascorbic acid content of the juice are presented but the complete data on the other constituents and their seasonal changes will be published as a technical bulletin of the United States Department of Agriculture.

### REVIEW OF LITERATURE

The chemistry and a summary of the vitamin content of foods have been published by Daniel and Munsell (8).

Clark (7) has noted that distribution of ascorbic acid in the coleoptile corresponds to the distribution of chlorophyll in plants grown in the light, but does not depend upon chlorophyll either for its presence or for its distribution in the coleoptiles of plants grown in the dark. Clark also noted ascorbic acid was not present in the germinating seed, but was synthesized in the coleoptile from a precursor in the seed. Matsuoka (15), working with rice, found that seeds germinated for 10 days under electric light contained more vitamin C than those germinated in the dark. He found that vitamin C was produced in the plant body in the dark but its content was markedly affected. Ijdo (12), speaking of photosynthesis says, "It seems plausible to suppose that there exists a direct relationship between photosynthesis and vitamin C content in view of the fact that the vitamin C content of leaves increases when they are irradiated with neon-light and that etiolated plants contain no vitamin C". Experiments of Randoin, *et al.* (18) support this theory. They found less vitamin C in white than in the green portions of plants. Batchelder and Overholser (1) found that the ratio of leaf area to fruit affects the vitamin C content only indirectly, that is, as it affects the size of the fruit produced. They pointed out that the ratio

<sup>1</sup>Acknowledgment is due Chase & Company, Windemere, Fla.; Mr. Arthur Butt, Orlando, Fla.; and the estates of Mary S. Compton, Orlando, Fla.; and H. R. Bruen, Merritt Island, Fla. for their generous cooperation; and to Mr. W. Robert Henry, Joffe C. David, Miss Doris Prophitt and Ward B. Matthews of this Division, and to L. M. Beacham, U. S. Food and Drug Administration, for their assistance in the work.



of the skin to the pulp is higher in small apples than in large ones and the skin contains a higher concentration of vitamin C than the pulp. Hou (11) found highest concentrations of vitamin C in the green or yellow skin of citrus, less in the white inner skin, and least in the juice. Reid (19) has presented some interesting data on the localization of ascorbic acid in the cowpea plant at different periods of development. On a milligram per gram basis leaf blades were much higher than petioles, and stems slightly higher than roots. Ijdo (12) also shows higher ascorbic acid content in leaves than stalks of spinach and indicates a relationship to photosynthesis.

The relation of soil fertilization to the vitamin C potency of foods has received little attention. In England two varieties of apples were tested by Bracewell *et al.* (5). They found that the nitrogen content of apples was not correlated with the vitamin C of the fruit. Some of the same authors (6) also have pointed out that the nature of the soil had no measurable effect on the vitamin C of oranges. Potter and Overholser (17) and also Batchelder (2) found that Winesap apples from trees receiving applications of complete fertilizer were better sources of vitamin C than apples from trees not so fertilized. Fellers *et al.* (9) have shown that the amount of potash and nitrogen used in the fertilization of asparagus did not appreciably affect the vitamin C or A content of the vegetable. Smith and Fellers (20) concluded that seasonal or other variations, except storage, caused little change in the vitamin C content in any one variety of apples. Ijdo (12), working with spinach, found that higher applications of nitrogen resulted in greater amounts of carotene and vitamin C. Increased ascorbic acid and increased yield accompanied applications of fertilizer, whereas Isgur and Fellers (13) found no ascorbic acid increase with New Zealand spinach.

Tressler and Mack (21) noted an increase in ascorbic acid as tomatoes ripened, whereas a decrease was noted in peas. The same authors (22) tested 17 varieties of peas under a single set of conditions. They noted that early small-seeded varieties contained more ascorbic acid than large-seeded varieties. In 10 varieties the vitamin C content decreased with increasing maturity. No correlation was found by Maclinn, Buck and Fellers (14) between size of tomato and vitamin C content; also ripeness had no significant effect upon the vitamin C content. In Palestine, Yofe and Yofe (23) found no constant relation existing between size of oranges and the amount of vitamin C in the orange juice, although it was apparent that vitamin C diminished late in the season.

French (10) determined the vitamin C content of Florida oranges during various stages of maturity. He found that vitamin C decreased at comparable rates to and beyond maturity in late ripening oranges (Valencia). With early oranges (Parson Brown) and midseason (Pineapple), an increase in the vitamin content at maturity precedes subsequent decline. French also pointed out that a high concentration of vitamin C in a given variety was associated with a high quality juice, but a juice of poor quality did not necessarily have a low concentration.

TABLE 1.—SEASONAL CHANGES IN THE ASCORBIC ACID CONTENT OF JUICE OF FLORIDA EARLY, MIDSEASON, AND LATE ORANGES 1936 to 1938 (RESULTS EXPRESSED IN MILLIGRAMS PER MILLILITER OF ORANGE JUICE)

Variety	Root-stock	Age of Trees (Years)	Location	1936-37			1937-38		
				Picked (1936-37)	Ascorbic Acid* (Milli-gram)	Taste	Picked (1937-38)	Ascorbic Acid* (Milli-gram)	Taste
Parson Brown	Sour Orange	15 and 16	Orlando, Florida	October 14**			August 31	.61	Acid, immature
				October 21†			September 13	.60	Acid—tart, immature
				November 4			September 27**	.55	Acid—tart, immature
				November 18			October 11	.57	Tart
				December 9			October 25	.58	Tart—pleasantly tart
				December 29			November 8†	.58	Pleasantly tart
				January 19			November 22	.57	Pleasantly tart
				February 10			December 16	.56	Pleasantly tart
				March 16			January 6	.56	Sweet
				May 3					
						Tart—slightly immature			
						Tart—pleasantly tart			
						Pleasantly tart			
						Pleasantly tart—Sweet			
Parson Brown	Rough Lemon	15 and 16	Orlando, Florida	October 14**			August 31	.52	Acid, immature
				October 21†			September 13	.54	Tart, immature
				November 4			September 27**	.47	Tart, immature
				November 18			October 11	.50	Tart, immature
				December 9			October 25	.48	Tart, watery
				December 29			November 8†	.48	Tart—pleasantly tart, watery
				January 19			November 22	.47	Tart—pleasantly tart, watery
				February 10			December 16	.46	Slightly tart, watery
				March 16			January 6	.43	Very insipid, watery
				May 3					
						Tart, watery			
						Tart, watery			
						Pleasantly tart, watery			
						Pleasantly tart, sweet			
Boone's Early	Rough Lemon	41	Windermere, Florida 1936-37 Fairville, Florida 1937-38	October 14**			August 31	.60	Acid, immature
				October 28†			September 13	.49	Acid, immature
				November 11			September 27**	.46	Tart—acid, immature
				November 23			October 11	.49	Tart
				December 16			October 25	.47	Tart, watery
				January 6			November 8	.49	Tart—pleasantly tart, watery
							November 22	.44	Tart—pleasantly tart, watery
							December 15	.46	Tart, watery
							December 28†		

"Sixteen" to One	Rough Lemon	11 and 12	Windermere, Florida	September 14**	.54	Insipid, sweet Insipid, sweet Very insipid Flavorless	August 30 September 13** September 27† October 11 October 25 November 8 November 22 December 16 January 6	.52 .53 .49 .48 .44 .50 .46 .51 .50	Tart, immature Tart, immature Tart, watery Slightly tart, watery Slightly tart, watery Slightly tart, watery Slightly tart, watery Slightly tart, watery
				September 30†					
				November 11					
				November 23					
				December 16					
Hamlin	Rough Lemon	11 and 12	Windermere, Florida	September 30**	.52	Tart, slightly immature Tart, watery Tart, sweet Tart—pleasantly tart Pleasantly tart Pleasantly tart, watery Sweet, watery	August 30 September 13 September 27 October 11 October 25** November 8 November 22† December 16 January 6	.48 .51 .49 .49 .47 .47 .46 .46 .46	Acid, immature Acid, immature Acid, immature Tart, immature Tart, immature Tart, watery Tart, watery Slightly sweet, watery
				October 14†	.50				
				November 23	.51				
				December 16	.40				
				January 19	.40				
Conner's Seedless	Sour Orange	21 and 22	Orlando, Florida	February 10	.36		August 31 September 13 September 27 October 11** October 25† November 8 November 22 December 16 January 6	48 48 48 49 46 51 48 53 52	Acid, immature Acid, immature Acid, immature Acid, immature Slightly acid, immature Slightly acid, immature Slightly acid, immature Tart Tart
				March 13					
				October 7**					
				November 4†	52				
				November 18	.53				
Homosassa	Rough Lemon	11 and 12	Windermere, Florida	December 9	.57	Tart—pleasantly tart Tart—pleasantly tart Tart—pleasantly tart Tart—pleasantly tart Tart—pleasantly tart	August 30 September 13 September 27** October 11 October 25 November 8 November 22† December 16 January 6	49 52 49 53 47 48 46 49 47	Acid, immature Acid, immature Acid, immature Acid, immature Slightly acid, immature Slightly acid, immature Slightly acid, immature Tart—pleasantly tart, watery Pleasantly tart, watery
				December 29	—				
				January 19	.53				
				February 10	.53				
				October 21	.55				
*Average of duplicate determinations. Variations not greater than 2.5 per cent of the amounts determined. **Legally Mature. †Plots Commercially Picked. ‡Fruit damaged by December 6 to 8, 1937 freeze. No commercial picking by March 8, 1938.				November 4**†	.51	Acid, immature Acid, immature Pleasantly tart Sweet Very sweet Insipid	August 30 September 13 September 27** October 11 October 25 November 8 November 22† December 16 January 6	49 52 49 53 47 48 46 49 47	Acid, immature Acid, immature Acid, immature Acid, immature Slightly acid, immature Slightly acid, immature Slightly acid, immature Tart—pleasantly tart, watery Pleasantly tart, watery
				November 18	.55				
				December 9	.51				
				December 28	.51				
				January 19	.43				
				February 10	.40				
				March 13	.38				

\*Average of duplicate determinations. Variations not greater than 2.5 per cent of the amounts determined.

\*\*Legally Mature.

†Plots Commercially Picked.

‡Fruit damaged by December 6 to 8, 1937 freeze. No commercial picking by March 8, 1938.

TABLE I—Continued

Variety	Root-stock	Age of Trees (Years)	Location	1936-37			1937-38		
				Picked (1936-37)	Ascorbic Acid* (Milligram)	Taste	Picked (1937-38)	Ascorbic Acid* (Milligram)	Taste
Jaffa	Rough Lemon	About 18	Winter Garden, Florida 1936-37				September 3	49	Very acid, immature
							September 13	49	Very acid, immature
		About 40	Tangerine, Florida 1937-38				September 27	.51	Very acid, immature
				September 15**			October 11	48	Acid, immature
Pineapple	Rough Lemon	32 and 33	Windermere, Florida	October 28	.46	Tart, slightly immature	October 25	47	Acid, immature
				November 11	.45	Tart, slightly immature	November 8	49	Acid, immature
				November 23	.42	Tart, watery	November 22	46	Acid, immature
				December 16†	.40	Pleasantly tart	December 6	46	Slightly acid
Seedlings		41 and 42	Orlando, Florida	January 6	—	Pleasantly tart—sweet	December 15	40	Tart
							January 30	48	Very acid, immature
				August			August 31	51	Acid, immature
				September 13			September 13	47	Acid, immature
				September 27			September 27	48	Acid, immature
				October 11**			October 11**	48	Acid, immature
				October 25			October 25	51	Acid, immature
				November 8			November 8	.50	Slightly acid, immature
				November 22	.51	Tart, immature	November 22	.48	Tart
				December 6			December 6	.50	Tart—pleasantly tart, watery
				December 16			December 16	.44	Pleasantly tart
				January 31†			January 31†	.40	Sweet, watery
				March 1			March 1	.42	Sweet, watery
				March 28			March 28	.58	Very acid, immature
				August 31			August 31	.55	Very acid, immature
				September 16			September 16	.53	Very acid, immature
				September 27			September 27	.54	Very acid, immature
				October 11			October 11	.56	Acid, immature
				October 25			October 25	.49	Acid, immature
				November 8			November 8	.49	Acid, immature
				November 22	.57	Very acid	November 22	.49	Slightly acid, slightly immature
				December 6	.53	Very acid	December 6	.54	Slightly acid
				December 17	.53	Very acid	December 17	.53	Pleasantly tart
				January 29†	.53	Acid—tart	January 29†	.53	Very sweet, slightly aged
				March 7	.47	Acid—tart	March 7		
						Pleasantly tart			

Valencia	Sour Orange	About 25	Merritt Island, Florida	November 27 December 16 January 9** January 25 January 16 February 1 March 18† March 9 April 4 May 24 May 24 June 24 July 25	.53 .53 .46 .48 .42 .42 .46 .42 .35 .36 .32 .29 .27	Very acid Acid Acid Acid, tart Tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart Sweet, watery Sweet, watery Acid Acid	November 30 December 17 January 10 January 28 February 10 February 28 March 15† March 26 April 27 May 20 June 11	.47 .41 .41 .41 .38 .27 .34 .36 .34 .30 .30	Acid, immature Acid, immature Slightly acid Slightly acid Tart Tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart Sweet
Valencia	Rough Lemon	About 25	Merritt Island, Florida	November 27 December 16 January 9** January 25 January 16 February 1 March 18† March 9 April 4 May 24 May 24 June 24 July 25	.53 .53 .46 .48 .42 .42 .46 .42 .35 .36 .32 .29 .27	Very acid Acid Acid Acid, tart Tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart Sweet, watery Sweet, watery Acid Acid	November 30 December 17 January 10 January 28 February 10 February 28 March 15† March 26 April 27 May 20 June 11	.47 .41 .41 .41 .38 .27 .34 .36 .34 .30 .30	Acid, immature Acid, immature Slightly acid Slightly acid Tart Tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart Sweet
Valencia	Sour Orange	27 and 28	Windermere, Florida	December 1 December 19** January 12 January 25 January 16† February 2 March 12 March 6 April 28 April 26 May 27 June 27	.15 .47 .51 .46 .44 .43 .36 .37 .31 .29 .27 .26	Acid Acid Acid Acid—tart Tart Tart Pleasantly tart Sweet Sweet Very sweet Very sweet, watery Very acid	November 30 January 3 January 15 January 31** February 14 March 1 March 14 March 28 April 21† May 21 June 13	.54 .54 .54 .51 .51 .47 .34 .30 .38 .36 .36	Acid, immature Acid, immature Acid, immature Tart Tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart Sweet Sweet
Valencia	Rough Lemon	32 and 33	Windermere, Florida	December 19 December 12** January 25 January 16 February 1 March 2 March 12 March 6† April 28 April 26 May 26 June 27	.45 .43 .40 .42 .42 .38 .32 .31 .39 .26 .26 .29	Acid Acid Acid Acid—tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart, watery Pleasantly tart, watery Sweet Sweet, watery	November 30 January 3 January 15 January 31** February 14 March 1 March 14† March 28 April 21 May 21 June 13	.57 .53 .53 .50 .53 .42 .31 .39 .30 .32 .31	Acid, immature Acid, immature Slightly acid, immature Tart Tart Pleasantly tart Pleasantly tart Pleasantly tart Sweet, watery Sweet, watery

\*Average of duplicate determinations. Variations not greater than 2.5 per cent of the amounts determined.

\*\*Legally Mature.

†Plots Commercially Picked.

‡Fruit damaged by December 6 to 8, 1937 freeze. No commercial picking by March 8, 1938.

TABLE I—*Concluded*

Variety	Root-stock	Age of Trees (Years)	Location	1936-37			1937-38		
				Picked (1936-37)	Ascorbic Acid* (Milli-gram)	Taste	Picked (1937-38)	Ascorbic Acid* (Milli-gram)	Taste
Valencia	Grapefruit	23 and 24	Windermere, Florida	December 1	.51	Acid	November 30	47	Acid, immature
				December 19	.51	Acid	January 3**	46	Slightly acid
				January 12**	.46	Acid	January 15	47	Slightly acid
				January 25	.44	Acid—tart	January 31	43	Tart
				February 16	.42	Tart	February 14	42	Pleasantly tart
				March 2	.39	Pleasantly tart	March 11†	39	Pleasantly tart
				March 13	.41	Pleasantly tart	March 14	29	Pleasantly tart
				April 6†	.35	Sweet	March 28	32	Pleasantly tart
				April 28	.35	Sweet	April 21	32	Pleasantly tart
				May 24	.32	Sweet	May 21	33	Sweet
				June 24	.30	Sweet	June 13	.31	Very sweet
				July 27	.19	Sweet			
				December 1	.55	Acid	November 30	50	Acid, immature
Valencia	Cleopatra	9 and 10	Windermere, Florida	December 19	.53	Acid	January 3	50	Acid, immature
				January 12**	.50	Acid—tart	January 15	52	Acid, immature
				January 25	.48	Acid—tart	January 31	48	Acid
				February 16	.42	Tart	February 14**	53	Tart
				March 2	.42	Tart	March 1	43	Pleasantly tart
				March 13	.44	Pleasantly tart	March 14†	31	Pleasantly tart
				April 6†	.41	Sweet	March 28	36	Pleasantly tart
				April 28	.37	Sweet	April 21	36	Pleasantly tart
				May 24	.34	Sweet	May 21	34	Sweet
				June 24	.33	Sweet	June 13	.29	Sweet
				July 27	.25	Sweet			
				December 1	.55	Acid	November 30	49	Acid, immature
				January 12**	.50	Acid	January 3	50	Acid, immature
Valencia	Rough Lemon Young Trees	9 and 10	Windermere, Florida	January 25	.48	Acid—tart	January 15**	49	Acid, immature
				February 16	.42	Tart	January 31	43	Tart
				March 2	.42	Tart	February 14	46	Tart
				March 13	.44	Pleasantly tart	March 1	42	Tart
				April 6†	.41	Sweet	March 14†	30	Pleasantly tart
				April 28	.37	Sweet	March 28	36	Pleasantly tart
				May 24	.34	Sweet	April 21	32	Pleasantly tart
				June 24	.33	Sweet	May 21	30	Sweet
				July 27	.25	Sweet	June 13	.29	Sweet, watery
				December 1	.55	Acid	November 30	49	Acid, immature
				January 12**	.50	Acid	January 3	50	Acid, immature
				January 25	.48	Acid—tart	January 15**	49	Acid, immature
				February 16	.42	Tart	January 31	43	Tart

Valencia	Sweet Orange	39 and 40	Windermere, Florida	December 1 December 19 January 12 January 25** February 16 February 12 March 12 March 6† April 28 May 24 June 28 July 27	37 .37 .40 .36 .37 .39 .31 .35 .27 .34 .28 .19	Acid Acid Acid Acid—tart Acid—tart Tart Pleasantly tart—sweet Sweet Sweet Sweet	November 30 January 3 January 15 January 31** February 14 March 1 March 14† March 28 April 21 May 21 June 13	38 .50 .43 .44 .46 .42 .28 .38 .37 .31 .33 .29	Acid, immature Slightly acid, immature Tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart Sweet Sweet, slightly watery Sweet
Valencia	Sour Orange	About 25	Orlando, Florida	December 2 December 18 January 12** January 25 February 16 February 12 March 12 March 6 April 3 May 24 June 28 July 27	63 .35 .35 .34 .33 .47 .49 .42 .42 .38 .38 .30	Very acid Very acid Acid Acid—tart Tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart			
Lue Gim Gong	Sour Orange	About 25	Orlando, Florida	December 2 December 18 January 12 January 25** February 16 February 12 March 12 March 6 April 3 May 24 June 28 July 27	61 .61 .56 .58 .52 .52 .54 .56 .47 .46 .38 .29	Very acid Very acid Acid Acid—tart Tart Tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart Pleasantly tart			

\*Average of duplicate determinations. Variations not greater than 2.5 per cent of the amounts determined.

\*\*Legally Mature.

†Plots Commercially Picked.

‡Fruit damaged by December 6 to 8, 1937 freeze. No commercial picking by March 8, 1938.

TABLE II—A COMPARISON OF THE ASCORBIC ACID\* CONTENT OF THE JUICE OF EXPOSED AND SHADED VALENCIA AND LUE GIM GONG ORANGES, APRIL 19, 1937 (RESULTS EXPRESSED IN MILLIGRAMS PER MILLILITER OF ORANGE JUICE)

Valencias**		Valencias†		Lue Gim Gong‡		Valencias§		Valencias¶	
Exposed Oranges (Milligram)	Shaded Oranges (Milligram)	Exposed Oranges (Milligram)	Shaded Oranges (Milligram)	Exposed Oranges (Milligram)	Shaded Oranges (Milligram)	Exposed Oranges (Milligram)	Shaded Oranges (Milligram)	Exposed Oranges (Milligram)	Shaded Oranges (Milligram)
.84	.53	.58	.48	.59	.52	.42	.30	.52	.39
.63	.51	.58	.48	.57	.49	.39	.29	.50	.38
.62	.50	.58	.48	.56	.48	.38	.28	.48	.35
.61	.50	.57	.47	.55	.48	.38	.27	.47	.35
.60	.50	.57	.47	.53	.48	.37	.25	.46	.34
.58	.49	.57	.46	.52	.47	.37	.24	.46	.33
.58	.48	.56	.44	.52	.47	.36	.24	.45	.32
.58	.47	.55	.44	.51	.46	.36	.24	.45	.32
.56	.46	.53	.42	.50	.44	.35	.23	.44	.32
.56	.44	.53	.42	.50	.44	.35	.23	.44	.31
.56	.44	.53	.41	.49	.44	.35	.23	.40	.30
.54	.43	.52	.41	.48	.43	.35	.22	.39	.30
.54	.43	.51	.40	.46	.41	.33	.22	.39	.30
.53	.42	.51	.39	.46	.41	.33	.21	.38	.28
.53	.42	.51	.39	.45	.39	.32	.21	.38	.28
.53	.42	.50	.38	.43	.38	.32	.21	.37	.27
.52	.42	.49	.37	.43	.38	.31	.20	.37	.26
.51	.42	.49	.36	.43	.37	.31	.20	.36	.26
.48	.40	.48	.35	.42	.37	.31	.20	.36	.25
.48	.39	.48	.34	.42	.37	.31	.18	.35	.25
.48	.38	.47	.33	.41	.37	.28	.18	.34	.24
.47	.38	.47	.31	.38	.37	.28	.18	.34	.24
.45	.34	.43	.27	.38	.27	.27	.17	.33	.19
Average	.45	.52	.40	.48	.42	.34	.23	.41	.30

\*Average of duplicate determinations. Variations not greater than 2.5 per cent of the amounts determined.

\*\*Valencia oranges, sour orange rootstock, Wabasso, Florida.

†Valencia oranges, sour orange rootstock, Orlando, Florida.

‡Lue Gim Gong oranges, sour orange rootstock, Orlando, Florida.

§Valencia oranges, rough lemon rootstock, Dundee, Florida.

¶Valencia oranges, rough lemon rootstock, Dundee, Florida.



During the Mediterranean fruit fly campaign in Florida, arsenical sprays were applied at frequent intervals. Nelson and Mottern (16) showed that the vitamin C content of oranges from repeatedly sprayed trees was considerably lower than oranges from unsprayed trees of the same variety and the same degree of maturity.

### METHODS AND MATERIALS

Determinations were started before the fruit reached legal maturity (that is, a ratio of 8 to 1 of the total soluble solids to the total acids in the juice) and ended with senescence, as indicated by "drying out".

The influence of various rootstocks, as well as the relative position of the fruit on the tree, especially with regard to exposure to sunlight, was investigated.

Ascorbic acid determinations were made in duplicate on the composited juice of 25 to 50 oranges. In addition, the ascorbic acid content was determined on the juice of each of 250 Valencia oranges.

In commercial groves, plots of about 25 trees were selected. Care was taken in the choice of both groves and plots, in order to avoid abnormal soil culture, fertilizer and spray practices.

Exceptionally young and old trees were avoided unless the fruit from these trees was wanted for comparative purposes. The trees used were from bud wood of known origin, coming from parent trees of known history, original seedlings or introductions. Mr. George M. Bahrt of the Division of Soil Fertility Investigations, of this Bureau, determined the soil types in the various groves and noted that the soils were uniform within each plot. They were well suited to the rootstocks used.

In addition to the "key plots" from which systematic collections were made, several state-wide collections were also made during 1936 to 1938, obtaining oranges of known history as to variety, rootstock and age. These were analyzed at the Orlando Laboratory. The findings were in close agreement with the results obtained from the key plots, indicating that the latter were representative.

Samples were usually collected at intervals of 2 weeks until the commercial picking of the plots. After the commercial picking, only two or three trees were reserved to supply fruit for later analyses. These were made at about monthly intervals, depending upon the amount of fruit reserved.

Oranges for all the tests were taken at random, care being exercised to pick only fruit from the same bloom. The ascorbic acid content in exposed and shaded fruit was determined by comparing 10 lots of 25 oranges each. Five of these were picked from outside branches, where the fruit was well exposed to sunlight, while the other five were from inside shaded branches of the same trees. The fruit samples were taken to the laboratory at Orlando immediately and placed in cold storage at 34 degrees F until tested. All the fruit was tested within a few days of picking. Ascorbic acid determinations were made in duplicate on each of the 250 individual oranges.

In determining the ascorbic acid or vitamin C content of oranges, the juice was extracted by hand squeezing, then strained to remove

pulp and seeds. The method used has been described by Bessey and King (4) and was the same as that followed by Beacham and Bonney (3). Essentially it consists in the titration of orange juice with sodium 2,6-dichlorobenzenoneindophenol (2,6-dichlorophenol-indophenol) solution which has been standardized against fresh commercial crystalline ascorbic acid.

### RESULTS

Table I presents the seasonal changes in ascorbic acid values of 11 varieties of Florida oranges for the two seasons, 1936-37 and 1937-38. In general, the results are in close agreement for the 2 years. The slight differences which exist might be due to seasonal conditions or to sampling errors.

It is of interest to note that early and midseason varieties of oranges have as high ascorbic acid content as the Valencias which have a much longer growing season, requiring approximately 12 to 16 months from bloom to harvest as compared with 7 to 12 months for the other varieties. It is also apparent from the data that no direct correlation was indicated between ascorbic acid and the palatability of the juice. This is shown by comparing the values given for "Sixteen to One", a poor quality early variety characterized by low total acid and total solids, with better varieties, such as Parson Brown, Boone's Early, Conner's Seedless and Valencia.

The highest amounts of ascorbic acid were usually found in immature oranges. As the fruit ripened the ascorbic acid gradually decreased. The lowest values were usually found late in the season, particularly with Valencias. On the other hand, in some of the early and midseason varieties little or no change in ascorbic acid content was noted as they ripened. Varieties which showed only a slight decrease were: Boone's Early, "Sixteen to One", Jaffa, Pineapple and Seedlings, while Conner's Seedless had slightly higher values late in the season, but these slight changes are probably not significant.

Some rootstocks seemed to have an influence on the ascorbic acid content of the fruit, especially up to the time of ripening, as may be observed in the data recorded for the Parson Brown variety. These oranges came from trees of the same age, grown side by side on a uniform soil, but the trees on rough lemon roots were larger than those grown on sour orange stocks. In Tables I and II it may be noted that the fruit from the sour orange stocks consistently contained the higher amounts of ascorbic acid. No significant difference in ascorbic acid content was found which could be attributed to the soil differences. This can be noted by comparing the data for Valencias from Merritt Island on the East Coast, where the soils are higher in organic matter, with those for the same variety grown in the sandy soils of central Florida where samples were obtained from trees grown on the same kind of rootstock. The ascorbic acid content of oranges grown on grapefruit, sweet orange, and Cleopatra stocks was about the same as of fruit grown on sour orange stock. No particular section of the State seemed to have fruit of a higher ascorbic acid content when a comparison was made with the same variety grown in other sections on like soils and

similar rootstocks. It was found, however, that fruit from certain groves had consistently higher ascorbic acid values than that from others. Whether this is due to culture, management or varietal strains has not been ascertained.

The results presented in Table II show that oranges exposed to sunlight had significantly higher ascorbic acid values than shaded fruit. The increase in ascorbic acid of exposed fruit over shaded fruit ranged from 14.3 per cent to 47.8 per cent. The ascorbic acid content per milliliter of juice in individual Valencia oranges exposed to sunlight and grown on sour orange rootstocks ranged from 0.43 to 0.84 milligrams, while that in shaded fruit from the same trees ranged from 0.27 to 0.53 milligrams. In exposed Valencia oranges grown on rough lemon rootstock it ranged from 0.27 to 0.52 milligrams as compared to a range of from 0.17 to 0.39 milligrams in shaded fruit from the same trees. In Lue Gim Gong oranges grown on sour orange rootstocks there was likewise considerable variation, the ascorbic acid content ranging from 0.38 to 0.59 milligrams for exposed fruit and from 0.27 to 0.52 milligrams for shaded fruit.

The analyses of individual oranges showed considerable variation within each lot of 25 but the range usually was of about the same magnitude.

#### SUMMARY

Early and midseason varieties of oranges have as high ascorbic acid content as late Valencia oranges.

No correlation was found between the ascorbic acid content of orange juice and quality, as judged by taste.

In Valencia oranges, a gradual decrease in ascorbic acid with ripening was noted. The highest values were associated with immature fruit, and the lowest values with senescent fruit (senescence indicated "crystallization" or drying out of pulp cells). In early and midseason varieties the trend of decreasing values was not so pronounced and was not always consistent.

Usually, smaller quantities of ascorbic acid were found when oranges were grown on rough lemon rootstocks than when grown on sour orange, grapefruit, sweet orange, and Cleopatra mandarin rootstocks, on all of which oranges ranged about the same in ascorbic acid content.

Significantly higher ascorbic acid values were found in oranges picked from outside branches which were well exposed to sunlight. Lower values were found in fruit from inside shaded branches.

Considerable variation in ascorbic acid was noted in tests made on individual oranges of the same sample, but the range was usually of about the same magnitude in each sample.

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## Preserving Cider by Carbonation

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PREVIOUS tests in the Ohio State University byproducts laboratory indicated that cider of excellent quality can be preserved for several months under high pressures of carbon dioxide. In one series of tests, filtered cider was kept for 3 months in a 10-gallon tin lined tank without any appreciable deterioration in flavor, although a small precipitate was formed and a slight taste attributed to tin could be detected. Some of this cider was transferred to 20 12-ounce crown sealed bottles and kept for an additional 3 months without a single case of spoilage even though there was less than 5 pounds carbon dioxide pressure in the bottles. Grape juice has also been held in our laboratory under 125 pounds pressure of carbon dioxide without any appreciable loss in flavor. At the conclusions of the 3 month periods of storage the samples of cider and grape juice were examined and found to be almost free from yeasts, molds and bacteria. Apparently this length of treatment is effective in forcing these fruit juices from spoilage organisms.

In several European countries where unfermented apple juice is consumed in large quantities the cider is first filtered through a coarse medium and held under high pressures of carbon dioxide to preserve the cider and throw down the colloids prior to germ proof filtration. Cider prepared in this manner has only a slight carbonated taste as the processes may be carried on at 70 degrees F where less than one volume of carbon dioxide is retained after the release of the pressure.

Several lots of cider condensed to approximately 26 per cent solids, by freezing or by means of a vacuum pan, were carbonated at  $3\frac{1}{2}$  volumes (*i.e.*, approximately 47 pounds pressure at 70 degrees F). Over 50 bottles of this cider have been kept for over a year without a single case of spoilage. This method of preservation is essentially the same method that is employed in preserving synthetic beverages. The high degree of carbonation is desired by some but is objectionable to many. Five ounces of the concentrate in 12-ounce bottles produced a better flavor than smaller or larger amounts. The concentrate prepared by freezing and centrifuging is superior to that prepared under 26 inches of vacuum.

During a recent Fruit School approximately 10 per cent of the growers rated the highly carbonated cider best. About 40 per cent indicated their preference for the slightly carbonated cider held under 125 pounds pressure of carbon dioxide. Other samples included flash pasteurized, frozen, pasteurized (20 minutes at 160 degrees F), and cider treated with the Matzka process (*i.e.*, treated with colloidal silver and heated to 140 degrees F). Approximately 20 per cent placed the Matzka processed cider in first place. Incidentally the tin in tin cans is said to react with pasteurized cider so that the cooked taste is largely eliminated after a few weeks time. Cider pasteurized in tin lined No. 2 cans in our laboratory did not have, in our opinion, a desirable flavor.

TABLE I.—RESULTS OF CIDER CARBONATION TESTS (1938)

Temperature (Degrees F)	CO <sub>2</sub> Pressures (Pounds)	Length of Treatment (Hours)	Total Number of Colonies	pH	Refractive Index	Swells Per Cent Cans	Days Stored in Cans	Canned Cider Internal Pressure		
72	25	1	Too many to count	4.15	1.3500	66	35	—	—	—
		6	380	3.8	1.3504	100	34	37	—	—
		12	286	3.72	1.3510	0	30	80	52	—
		20	438	3.60	1.345	66	27	50	—	—
72	50	1	446	3.5	1.345	100	49	50	—	—
		6	301	3.5	1.3508	100	26	—	—	—
		12	247	3.5	1.3512	33	26	47	41	—
		20	157	3.5	1.3517	66	27	78	—	—
72	25	1	182	3.6	1.3495	66	27	—	—	—
		6	135	3.6	1.3498	0	25	—	—	—
		12	207	3.58	1.3498	0	25	15	63	76
		20	165	3.55	1.3500	33	24	49	60	76
72	100	1	200	3.53	1.3504	0	24	66	28	36
		4	112	3.53	1.3508	0	24	62	76	48
		8	161	3.5	1.3506	0	24	80	30	—
		12	272	3.51	1.3500	0	24	77	80	—
72	125	1	144	3.6	1.3500	66	23	50	—	—
		4	161	3.5	1.3500	33	23	86	23	—
		8	94	3.52	1.3502	0	23	80	35	—
		12	—	3.51	1.3498	33	23	44*	68	73
38	25	1	—	3.6	1.3500	100	23	4.5*	1*	—
		6	465	3.5	1.3501	33	21	37	—	—
		12	325	3.5	1.3492	100	21	—	—	—
		20	251	3.57	1.3500	66	21	—	—	—
38	50	1	167	3.6	1.3500	33	20	52	45	—
		6	129	3.51	1.3506	100	20	—	—	—
		12	—	3.5	1.3502	66	20	47	—	—
		20	—	—	1.3514	—	20	—	—	—
38	75	1	201	3.52	1.3508	66	19	27	—	—
		6	180	3.49	1.3505	66	19	62	—	—
		12	105	3.5	1.3480	100	19	—	—	—
		20	175	3.58	1.3510	100	19	—	—	—
38	100	1	178	3.56	1.3502	66	18	60	—	—
		4	131	3.59	1.3502	33	18	26	26	—
		8	120	3.62	1.3497	100	18	—	—	—
		12	102	3.62	1.3492	66	18	80	—	—
38	125	1	207	3.68	1.3520	66	18	—	—	—
		4	133	—	1.3492	—	18	—	—	—
		8	55	—	1.350	66	18	80	—	—
		12	60	—	1.3499	100	16	—	—	—
4 days	—	4	90	—	1.3495	—	16	—	—	—
		8	56	—	1.3489	—	16	—	—	—
		12	48	—	1.3498	—	16	73	1*	—
		20	80	—	1.3498	—	16	4.5*	—	—
4 days	—	4	100	—	1.3500	—	16	—	—	—
		4	—	—	—	—	—	—	—	—

Before the treatment with high pressures of carbon dioxide can be used profitably it will be necessary to shorten the treatment or complete the treatment in containers that withstand internal pressures of from 75 to 100 pounds per square inch. To test the effectiveness of shorter treatments different batches of cider were treated for 1, 6, 12, and 20 hours under 25, 50, 75, 100, and 125 pounds pressure of carbon dioxide in the tin lined tank. Following this treatment the pressure was released and the cider was transferred to sterile flasks and then into sterile beer cans capable of resisting 100 pounds per inch of internal pressure. Reasonable care was taken to avoid contaminations with microorganisms. The effects of the treatments are presented in the Table I.

It is obvious that the higher pressures and longer treatments are most effective in reducing the number of microorganisms. There are no changes in refractive indices. The longer carbon dioxide treatments do not increase the acidity appreciably. The quality of the canned product can be predicted fairly accurately from the amount of internal pressure which is developed. Several of the cans filled with cider after the 75, 100, and 125 pound treatments with carbon dioxide developed less than 20 pounds pressure. The flavor of these samples was usually very good.

It is, however, obvious that none of these treatments are commercially successful as excessive pressures developed in some cans of all lots and undesirable flavors were always associated with the high pressures. In some instances the pressures were sufficient to burst the can.

# Internal Gas in Fruits as Influenced by External Treatments I. Carbon Dioxide

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SOME attention has been given during the past 20 years to the gases found in plant tissues which are related to normal respiration, namely, carbon dioxide and oxygen. With the possibilities now under investigation of the use of carbon dioxide atmospheres in the storing and shipping of fruits and vegetables, the importance of determining the effects of external atmospheres upon the amount of carbon dioxide and oxygen in the fruit tissue is becoming more important. Also certain paraffin base waxes are now being used on a commercial scale with some fruits and vegetables, and the prospects are that more of these products will be used in the future. Since one function of these waxes seems to be to influence the rate of gas exchange which in turn may have an effect on the quality of the product, the study of internal gases may shed some light on the results obtained.

With the need for such studies in mind an effort was made in 1938 to determine the amount of carbon dioxide in fruits held in atmospheres containing varying amounts of carbon dioxide and also that in fruits which had previously been dipped in water emulsion of various commercial waxes. Both types of test were studied at several different temperatures ranging from 32 to 70 degrees F and with several kinds of fruit.

## METHOD

The methods used in the past by a number of investigators (1, 2, 3, 4, 6) for determining internal  $\text{CO}_2$  have been fundamentally similar, using mercury to surround the plant tissue and then subjecting it to a vacuum, thus liberating gases from within the fruit. The gas was then expelled, measured and analyzed. In the procedure it was necessary to standardize the time and amount of vacuum.

While this method has many good features, and perhaps is suitable when comparing fruits of one variety it may not give a true picture of the internal atmosphere. The method must be standardized both as to time and amount of vacuum in order to obtain comparable figures which are empirical in nature. In the first place it is highly probable that the method does not give the true picture of the gases in the intercellular spaces since the creation of a partial vacuum with consequent withdrawal of gases from the spaces in the tissue, immediately upsets the equilibrium balance existing between the gases in solution in the water of the plant tissue and the gases in the intercellular spaces (Henry's law). Since the vacuum method may give neither the intercellular gas nor total gas a method giving total  $\text{CO}_2$  may be more valuable. Furthermore, in order to affect the respiratory processes it seems probable that gases must be in solution, and therefore the desired information is the amount of gases in the fruit and not just in the intercellular spaces. Due to its solubility,  $\text{CO}_2$  is certainly present in



greater total amount in the water of plant tissue than in the intercellular spaces which are a relatively small percentage of the volume of most fruits.

Because of the undesirable features of the vacuum method of analysis, the following method was devised and has proven suitable for internal  $\text{CO}_2$  determinations (Fig. 1). One hundred cubic centimeters of half normal NaOH were placed in a heavy walled liter Erlenmeyer flask and about 200 cubic centimeters of distilled water added. Approximately 400 grams of fruit were weighed out and dropped into the alkaline solution. Small fruits such as cherries and plums were used whole, whereas larger fruits such as apples, peaches and pears were sliced rapidly and dropped into the solution. The pits were removed from peaches being tested. By using an alkaline solution, the loss of  $\text{CO}_2$  during the preparation of the sample was slight. The contents of the flask were then acidified and connected to a  $\text{CO}_2$  free air line by means of a double stopper. Air was bubbled continuously through the solution containing the fruit, and then carried through a trap flask and bubbled into an absorption tower containing 100 cubic centimeters of half

normal NaOH and enough water to give about 8 or 10 inches of liquid. Bubblers with sintered glass disks made according to the method described by Kirk (5) were used to break the bubbles up finely and in addition a few drops of butyl alcohol were added to increase surface tension, thereby breaking the air stream into a fine froth. The flask was placed over a flame or hot plate and brought to a boil. In order to assure the driving off of all  $\text{CO}_2$  boiling was allowed to continue for 5 to 10 minutes. A number of tests where boiling was continued for an hour or more gave similar results indicating complete removal of  $\text{CO}_2$  in 5 to 10 minutes of boiling.

The NaOH solution was placed in a 500 cubic centimeter volumetric flask and brought up to volume. Fifty cubic centimeter aliquots to which an excess of barium chloride had been added were titrated with tenth normal HCl using thymol blue and cresol red as indicators. The disappearance of the blue and continued presence of pink at a pH

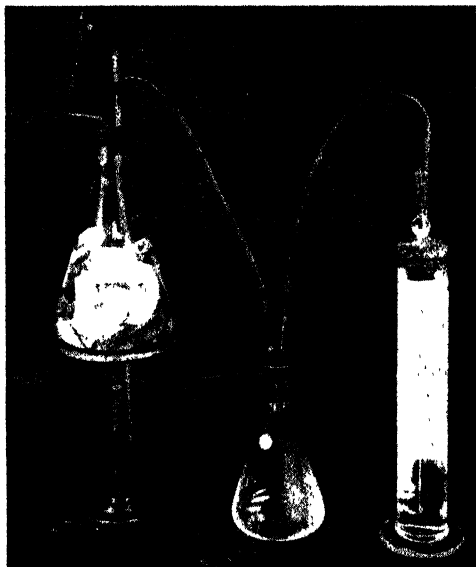


FIG. 1. Simple type of apparatus used in determining internal  $\text{CO}_2$ .

of about 7.8 was used as the end point since no carbonate is affected in this range. The data obtained from these titrations agreed almost perfectly with titration of the carbonate either after titrating the excess alkali or by filtering and re-dissolving the precipitate. This would indicate that  $\text{CO}_2$  was the only product of importance which had been expelled from the fruit and re-absorbed by the alkaline solution.

## RESULTS

*Fruit Stored in  $\text{CO}_2$  Atmospheres:*—Several different kinds of fruit, including apples, pears, peaches, nectarines and plums, were held in atmospheres varying in  $\text{CO}_2$  content from that of air up to 85 per cent and at temperatures of 32, 40, 45, and 70 degrees F. Analyses according to the described method were made on duplicate lots of these fruits to determine the internal  $\text{CO}_2$  content (Fig. 2).

The internal  $\text{CO}_2$  content of the fruit stored varied from about 100 milligrams to 400 milligrams per kilogram of fruit with quite similar results in a temperature range from 32 to 70 degrees F. Fruits with high rates of respiration contained the greatest amounts of  $\text{CO}_2$ . For example, apricots were relatively high and Winter Nelis pears low in internal  $\text{CO}_2$ . As the percentage of  $\text{CO}_2$  in the external atmosphere was increased the amount of  $\text{CO}_2$  in the fruit tissue also increased. The amount of  $\text{CO}_2$  in various fruits also became more nearly similar. Some tests showed over 1,700 milligrams of  $\text{CO}_2$  per kilogram of fruit. Greater amounts of  $\text{CO}_2$  were found in the fruit under similar atmospheres as the temperature was lowered.

The data obtained were compared with theoretical values of the solubility of  $\text{CO}_2$  in water at various partial pressures and temperatures, assuming that the fruits were 85 per cent water. The results of actual determinations were always higher than theoretical results, but the variation became very small as the external atmosphere approached 100 per cent  $\text{CO}_2$ . This behavior was expected since respiration of the fruit tissue modifies the internal atmosphere, increasing its  $\text{CO}_2$  content above that in the external atmosphere. If a correction is made by subtracting the milligrams of  $\text{CO}_2$  present in the fruit in air from the amount in  $\text{CO}_2$  atmospheres, the results will fall close to the theoretical value of solubility of  $\text{CO}_2$  in water. This correction will vary with the  $\text{CO}_2$  content of the external atmosphere becoming zero in an atmosphere of 100 per cent  $\text{CO}_2$ , since at this point the internal and external atmospheres would be identical regardless of respiration. The amount of intercellular space in the fruit will also tend to keep the total  $\text{CO}_2$  a little higher than the theoretical values.

*Waxed Fruits:*—The same kind of fruits held in  $\text{CO}_2$  atmospheres were also covered with various commercial water emulsions of waxes. Paraffin was the principle wax component although some waxes were part carnauba wax. Three different emulsifying agents were used.

The internal  $\text{CO}_2$  content of waxed fruits varied considerably more than was the case with gas stored fruits. As a general rule the  $\text{CO}_2$  content of fruits was increased by a film coating of wax. This was not a direct relationship with the sealing power of the wax, at least for water vapor. In one experiment a certain wax, which gave the highest

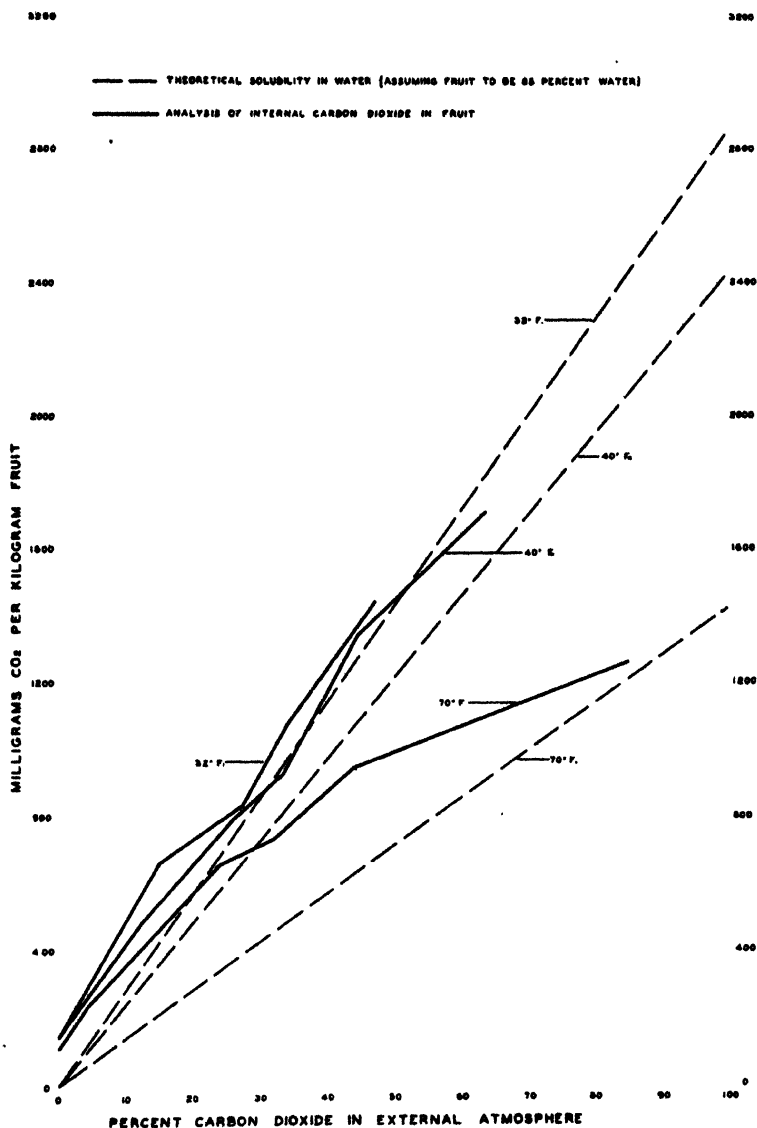


FIG. 2. Carbon dioxide found in pear fruits compared with amounts in water calculated from solubility tables.

internal amount of CO<sub>2</sub> of any waxes tested, increased the content in Bartlett pears from about 225 milligrams found in the control to 450 milligrams per kilogram of fruit. However, this wax was less successful in preventing water loss than some others. Bartlett pears coated

with a film of this wax remained green and hard for over 90 days at 70 degrees F compared to control lots that ripened in 4 to 5 days.

The build-up of  $\text{CO}_2$  in waxed fruits was highest from one to a few days after treatment, declining thereafter, and in some cases becoming less than the control. This is particularly true at ripening temperatures indicating that the rate of oxygen absorption may be reduced by the waxes.

More  $\text{CO}_2$  was generally found in waxed fruits at 45 degrees and at 70 degrees F than at 32 degrees F. This is probably the result of the combined influence of solubility of  $\text{CO}_2$ , respiration rate and rate of diffusion of gases through the wax coating.

### DISCUSSION

Since the gases in the intercellular spaces cannot be accurately separated from those in solution in water in the plant tissue the determination of total  $\text{CO}_2$  in the tissue seems more desirable in studying the effects of gas storage and waxing of fruits and vegetables than percentages or amounts obtained by more empirical methods.

The results of investigations presented here indicate that the amount of  $\text{CO}_2$  found in fruits bears a close relationship with solubility curves of  $\text{CO}_2$  in water. This gas is of course in equilibrium with the atmosphere in the intercellular spaces, but since the volume of intercellular space is small compared to that filled with liquid the amount of  $\text{CO}_2$  in the intercellular spaces is also correspondingly small. There is need for further tests to chart more completely the curves for different fruits, the establishment of which should be of considerable value to future investigations.

Information relative to the  $\text{CO}_2$  content of fruits under varying conditions is important and should serve as an aid in determining reasons for injury in gas storage. However, the picture cannot be nearly complete until the same information is available for oxygen. The mercury evacuation method is probably more accurate with oxygen than with  $\text{CO}_2$  because of the lower solubility of oxygen in water. However, it would seem that this should also be re-checked with other methods because of its importance in the study of waxed fruits and gas storage with high  $\text{CO}_2$  and low oxygen.

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## An Evaluation of Ninety-six Apple Varieties at the 21-Year Period Under Illinois Conditions<sup>1</sup>

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THIS paper is a report on the performance of varieties in the apple variety orchard at Urbana, Illinois. The data are presented to place on record the performance of some of the varieties that were highly recommended by our forefathers, as well as varieties that still remain on many recommended planting lists.

Although this orchard was set as a variety test orchard and undoubtedly the nurseries supplying the trees were informed of their use, it is of interest to note the number of trees not true to name. The list includes the following, the ordered variety appearing first with the received variety following: one Yellow Bellflower, Chenango; two Hubbardston, Northern Spy; two Red June, Early Harvest; one Rhode Island Greening, Stark; one Rhode Island Greening, not identified; one Stayman Winesap, Winesap; one Summer Rambo; Turley; one William's Red, Ingram; three Willow Twig, not identified, all three different; one Melon, Winter Banana; two Melon, not identified; three Giant Geniton, Grimes Golden.

### CULTURAL TREATMENT

The 2-year-old variety trees were set in the fall of 1917. They were set on the square with trees at 36 by 36 feet intervals. Filler trees were planted between the variety rows and also in the intervals between the variety trees in the fall of 1918. This gave an orchard 18 by 18 feet. All fillers except those in the center of the permanent squares were removed in the winter of 1931. Those in the center of the squares were taken out in the winter of 1935.

A bluegrass sod strip about 6 feet wide has been maintained along the tree rows after the trees were 4 years old. Cultivation around the young trees was given at frequent intervals. This practice was stopped when the trees were large enough to partially shade out the sod close to the tree trunk. Cultivation with a disk harrow between the sod strips has been practiced each year except for the past 2 summers. During the early life of the orchard, four to five diskings were given each year. This was reduced to two after 1930. The only fertilizer applied was a 2-pound per tree application of nitrate of soda, given in the spring of 1934.

All trees have received the same early season sprays. On early ripening varieties the late summer sprays were omitted. Although apple scab and codling moth have not been kept under the best of control, these troubles have not reduced the yields appreciably.

After the trees were set, the conventional heading-back type of pruning generally recommended in Illinois up to about 1925 was given the trees. Apparently a follow-up pruning after the initial heading-back to reduce the number of scaffolds and give better spacing was not given the trees. In 1925 a heavy pruning was given all trees in reducing the

TABLE I—SHOWING THE YIELD, BLIGHT SUSCEPTIBILITY, AND WINTER INJURY TO 96 APPLE VARIETIES

Variety	Age of Initial Bearing (a) (b)		Age When 50-Pound Yield First Produced in Single Year (a) (c)		Total Yield (Pounds) Including 1938 Crop (a)		Fire Blight (g)	Winter Injury	
								Trunk (h)	Crotch (h)
Akin	20	20	21	0	231	38	5	0	0
Alexander	8	8	20	20	225	402	5	0	0
Arkansas	10	10	14	14	620	1121	2	0	1
Arkansas Black	10	10	12	17	1155	326	0	1	0
Autumn Strawberry	8	7	5	8	1139	1215	0	0	0
Baldwin	12	10	10	20	1179	1599	1	2	0
Barnett	10	10	20	20	385	414	1	0	0
Ben Davis	6	6	13	20	1604	1108	1	0	0
Benoit	6	20	11	15	1260	590	5	0	0
Bismarck	14	14	0	0	110	46	2	0	3
Black Ben Davis	6	11	14	15	533	898(f)	0	0	1
Black Gilliflower	12	12	14	20	726	1317	3	0	0
Champion	7	7	13	11	535(f)	1519	0	0	2
Chenango	7	8	14	15	1293	1203	7	0	0
Delicious	12	12	20	14	1302	1266	2	0	0
Delicious	12	12	18	18	2468	350	2	4	3
Dr. Matthews	9	10	0	14	877	237	0	0	1
Dudley	4	5	14	7	2045	2899(d)	0	0	0
Early Harvest	7	7	20	19	866	1050	2	0	0
Early Ripe	15	12	20	20	378	520	0	1	3
Esopus	19	0	0	0	88	526	5	3	3
Fallawater	6	15	0	0	17	0	3	0	2
Fall Pippin	12	10	16	14	293	3542	7	0	1
Fameuse	10	10	16	18	2362	1247	0	0	0
Fanny Crab	5	6	14	14	106	1297	2	0	0
Golden Crab	6	6	14	14	539	361	0	0	0
Golden Sweet	10	10	11	11	1260	1094	3	0	1
Golden Winesap	20	20	20	20	1523	1675	2	0	1
Gravenstein	20	18	12	9	535	449	2	0	0
Grimes	7	7	12	12	1725	1981	2	0	0
Grimes (double worked)	7	7	12	12	788	1595	2	0	2
Hubbardsston	12	12	0	0	2459	176	2	0	2
Huntsman	19	15	20	20	176	0	4	1	0
Idared	5	7	20	20	991	795	0	0	0
Jonah Crab	7	10	14	14	230	279	3	0	0
Jonah	15	11	12	12	1900	1679	0	0	0
Jonathan	9	6	20	20	315	648	3	0	0
King David	9	9	16	14	691	859	2	0	0
Kinnard	10	7	14	14	2280	2033	2	0	0
Lady Sweet	19	20	14	14	1055	1080	3	0	0
Lawyer	12	12	0	0	246	48	0	0	0
Lavland Raspberry	12	10	0	0	677	273	3	0	1
Lowell	17	18	20	20	22	0	0	0	0
McClure	10	10	12	12	365	175	7	1	0
McClure	10	10	12	12	1765	1825	0	0	0
McMahon	12	10	20	20	1599	46	2	0	3
McMahon	12	16	16	20	346	168	2	0	1

Apple Variety	16	7	9	20	14	21	322	1138	364	3	0	0
Minkler	16	7	9	20	14	21	322	1138	364	3	0	0
Mother	13	16	16	20	20	18	968	671	737	2	3	3
Nero	9	17	19	20	20	0	616	212	0	5	3	3
Northern Spy	7	19	19	19	19	19	1645	2632	2313(e)	0	0	0
Northern Greening	7	19	19	19	19	19	1645	2632	2313(e)	0	0	0
Oldenburg	10	7	10	16	10	14	841	727	1145	0	0	0
Ortleb	10	7	10	17	17	17	265	1159	632	1	0	0
Pargon	10	10	14	12	10	17	1604	1848	1784	0	0	0
Patten	7	5	7	12	11	8	484	1710	1071	0	0	0
Ralls	21	12	12	21	16	15	500	1128	563	3	5	1
Ramsdell Sweet	15	20	15	20	20	20	564	477	48	2	5	0
Red Astrachan	20	20	20	20	20	0	191	57	73	2	0	0
Red Canada	7	11	20	20	20	21	945	652	73	0	2	0
Red June	16	—	—	20	—	—	359	—	—	2	3	3
Rhode Island Greening	15	—	—	20	—	—	396	—	—	5	1	0
Romanic Little Red	7	7	10	10	12	12	2051(f)	1074(f)	1762(f)	4	4	4
Romanic Red	7	9	10	15	15	14	1831	1602	—	0	0	0
Romanic Sweet	7	10	10	15	15	14	352(d)	646(f)	—	3	2	2
Rosbary Beauty	9	14	12	20	20	18	212	102	54	2	0	0
Salome	12	14	12	18	18	18	953	563	862	2	0	1
Senator	11	10	11	16	11	14	736(f)	826(f)	690(f)	5	5	1
Shiawasee	—	—	—	—	—	—	—	—	—	7	0	1
Stark	10	8	10	14	15	14	1727	1532	1034	3	0	0
Stayman Winesap	10	—	10	12	—	14	180	—	824(f)	0	0	0
Summer Rambo	—	—	15	—	—	17	—	—	132	0	0	0
Sutton	12	10	10	0	0	0	6	54	12	5	5	3
Sweet Bough	8	8	8	19	19	19	333	471	671	7	0	1
Tolman Sweet	17	11	7	20	17	18	114	131	506	4	0	0
Thompson King	12	20	12	20	13	0	311	1723	57	0	2	0
Turkey (one tree only)	—	—	—	—	—	—	—	—	—	0	0	0
Vanderwe	6	6	9	20	16	17	807	1029	779	0	0	0
Vanderwe	6	6	7	9	18	18	919	607	398	7	0	0
Wagner	7	9	7	11	20	20	1105	170	1138	2	3	3
Walkers Beauty	10	10	12	20	16	16	155	689	547	0	0	0
Wealthy (double worked)	5	10	10	11	10	20	670(f)	393(f)	249(f)	1	0	0
Weismar Dessert	20	20	20	20	20	20	605	520	450	3	3	3
White Pippin	12	12	18	20	20	20	952	670	309	5	3	4
White Winter Pearmain	12	14	21	18	18	21	797	434	49	4	4	4
Williams Red	10	14	—	16	19	—	477	451	—	3	0	0
Wilson Red June	15	15	15	15	16	0	226	93	56	0	0	0
Windsor	10	15	16	12	10	26	385	93	385	5	0	1
Winesap	10	15	16	12	10	26	385	93	385	5	0	1
Winesap	10	15	16	12	10	26	385	93	385	5	0	1
Wolf River	5	15	10	10	15	14	1522	1474	985(d)	2	0	0
Yellow Bellflower	11	12	12	15	15	15	1846	2334	1543	3	0	0
Yellow Newtown	20	21	12	15	15	15	1452	1362	1133	0	0	0
Yellow Transparent	6	5	5	20	0	0	270	30	134	1	0	1
York Imperial	10	7	10	12	8	12	853	1112	1266	5	3	3
York Imperial	10	7	10	12	12	17	862	1270	566	6	2	0

(a) A bar (—) in the first nine columns indicates that the tree died at an early age or that the tree was not true to name.

(b) 0 indicates no fruit produced up to and including 1938.

(c) An 0 in the last nine columns indicates that the tree has not produced as much as 50 pounds in any one year.

(d) Died 1939.

(e) Died 1937.

(f) Died 1938.

(g) 0 = none, 1 = very scarce, 2 = scarce, 3 = medium, 4 = medium to severe, 5 = severe, 6 = severe to very severe, 7 = very severe.

(h) 0 = no apparent injury, 5 = very severe.

number of scaffold. Following this heavy pruning, little was done until 1928, when light pruning was given all trees. This has been the practice since 1928.

The soil is classed as Brown silt loam (Illinois classification previous to 1933).<sup>1</sup> The lower strata are pervious to water. In the orchard the maximum difference in elevation is about 4 feet.

## RESULTS

The pertinent data taken in this orchard are shown in Table I. It does not seem necessary to elaborate on these data, yet a few remarks seem advisable. In age of initial bearing, 57 per cent of the trees produced their first fruits at or before the tenth year. At the other extreme two Fallawater, one Hubbardston and one Liveland Raspberry have failed to produce to date, and further, they have never bloomed. With most of the varieties represented by three trees, all three trees came into production at about the same time, while a few showed considerable variability in initial bearing.

In columns 4 to 6 are shown the tree age when 50 pounds of fruit was first produced in a single year. Comparing these ages with the ages of initial bearing, it will be seen that with most varieties it took more than 3 years before the trees produced 50 pounds after they produced the first fruit. It will also be noted that some trees have never produced as much as 50 pounds in a single year. In this connection it must be remembered that a heavy pruning was given in 1925. This pruning probably delayed fruit bud formation on many varieties and thus delayed for a few years the age of initial bearing. Trees that had produced previous to the heavy pruning might be expected to be thrown out of fruit bud production, providing the pruning was severe. The yearly records show this to be the case. Most of the trees that were fruiting previous to 1925 did not produce again until 1928 or after and then came in with light crops. A similar condition has been recorded in a block of 100 Jonathan, very heavily pruned in 1925 at the fifth year of age. These trees commenced to produce at the twelfth to fourteenth years and then came in with light crops.

The total yields are shown in columns 7 to 9. Trees that died in 1936, 1937 or 1938 have the yields included up to the time they died. Such trees are indicated in the table. In checking over the yields it will be seen that there are very great differences between varieties and also between trees of the same variety. The total yields, even for the varieties producing the most fruit, cannot be considered large. As mentioned above, the heavy pruning has undoubtedly reduced yield to a greater or lesser degree. Also the fact that filler trees were present may have had an influence on production. It should be mentioned, however, that even during the severe drought years there was no apparent injury to either the variety or filler trees that could be associated directly with a deficient water supply. Even though yields were low, probably the

<sup>1</sup>The selection of varieties and care of the orchard up to about 1920 was under the direction of Professor B. S. Pickett. Mr. F. E. Carver was in charge from about 1920 to 1924 and Professor W. S. Brock in 1925 and 1926. The writer has been responsible for the orchard since 1927.



varieties would hold about the same general rank if grown under other conditions.

Column 10 presents data on the susceptibility to fire blight taken in June 1929, a year when this disease was very severe. In the check-up in the orchard, "very severe" was used only for varieties that had every terminal and every spur blighted to some degree. "None" included varieties on which not a single blighted terminal or spur could be found. "Medium to severe" was used as the midpoint in severity of infection. In checking over the varieties it will be noted that some varieties were rated low in susceptibility in 1929 yet in other years, at least in Illinois, are considered relatively susceptible.

A check on winter injury was taken in the summer of 1936 following the cold winter of 1935-36. When checking on the severity of injury, small pieces of bark were removed from the trunk and crotches of every tree to determine the extent of the injury. It was thought by following this practice that any slight injury could be detected. In this check the amount of bark splitting and dead bark was used as the index of winter injury. On the trunk, "Class 5, was severe" was used for varieties on which the bark was split from the ground line to the lowermost limb with loosening of the bark at least half way around the trunk. This same class, that is Class 5, was used for crotch injury when dead bark was found at the inner angles of all the scaffolds.

Although trunk and crotch injury give some indications relative to winter injury, it has been apparent that many trees were injured that did not exhibit this condition. Such trees are noted as died in 1936, 1937 or 1938 in columns 7 to 9. The differences in amount of trunk and crotch injury could not be associated with cropping, pruning, soil type or drainage, therefore, the injury probably can be considered the relative susceptibility of the varieties.

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## Plum Variety Trials in Central Washington<sup>1</sup>

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**I**N the part of the state west of the Cascade Mountains in which most of the plums are grown, the annual rainfall varies from 60 to 100 inches. In the irrigated valleys of Central Washington the rainfall is only 3 to 15 inches. Other climatological factors and soil conditions are markedly different.

Plum variety trials have been conducted at the Irrigation Branch Experiment Station at Prosser. Hence, the discussion is limited to Central Washington conditions.

### CLIMATE, SOIL, AND CULTURE

*Climate:*—A summary of the climate at the Irrigation Branch Experiment Station, Prosser, Washington, from 1930 to 1937 inclusive, is given in Table I.

TABLE I—WEATHER SUMMARY FOR IRRIGATION BRANCH EXPERIMENT STATION, PROSSER, WASHINGTON (INCLUDING ANNUAL MEAN, HIGH AND LOW TEMPERATURES AND TOTAL PRECIPITATION)

Crop Year October 1 to October 1	Mean Temperature (Degrees F)	Lowest Minimum Temperature (Degrees F)	Date of Lowest Temperature	Highest Maximum Temperature (Degrees F)	Date of Highest Temperature	Total Rainfall (Inches)
1929-30	50.1	-19.5	January 21	103	July 13	4.58
1930-31	52.0	12.0	January 1	104	July 20	2.74
1931-32	50.2	- 3.0	February 3	100	August 7	7.80
1932-33	50.6	- 8.0	February 9	102	{ June 14 August 15, 16	7.89
1933-34	55.2	21.0	December 1	105	July 27	5.91
1934-35	51.6	- 6.0	January 20	103	July 14	4.57
1935-36	50.3	- 4.0	February 17	103	July 21, 22	6.57
1936-37	49.1	-14.0	January 31	103	July 25	7.09
1937-38	52.7	15.0	February 2	107	July 14	9.73

The records show that the annual rainfall varied from 2.74 inches in 1930-31 to 9.73 in 1937-38, and occurred usually during November to January inclusive. Very few rains occur during the summer months, necessitating irrigation.

The summer temperatures are usually high and may reach maxima of 100 to 107 degrees F. Low temperatures that might result in damage to plum trees occurred during not to exceed three of the eight winters. One such occasion was during the fall of 1935. After a mild autumn the temperature suddenly dropped to 11 degrees F on October 30 and by November 3 had reached 5 degrees F with the result that the less hardy or late maturing varieties were injured because they had not become fully dormant. Spring frosts as late as May 6 may cause serious damage during and after the blossoming period.

Severe windstorms often cause damage by breakage of branches, especially during the summer months when there is a heavy load of foliage and fruits.

<sup>1</sup>Published as scientific paper No. 400 of the College of Agriculture and Experiment Station, State College of Washington.

*Soil and Soil Management:*—The soil (1) of the variety orchard is classed as Sagemoor fine sandy loam, of light grayish brown color with an average depth of about 12 inches. The subsoil to a depth of 30 to 36 inches or more is a gray, compact, very fine sandy loam resting on stratified material of the same color and texture many feet in depth. The surface drainage and underdrainage are good. Under irrigation this soil is comparatively fertile and productive. Until 1919 this land was in a virgin state with its cover of the native grasses and sage brush. In the plum orchard a cover crop of alfalfa is allowed to grow and rot on the ground without cultivation. Irrigation water is applied in corrugations 3 feet apart, at intervals of approximately 20 to 30 days for 5 months during the summer. About 40 acre inches of water are applied during each growing season. These practices promote a vigorous, healthy growth and development of the trees and cover crop.

*Trees and Culture:*—Cultural practices in the plum orchard were similar to those used commercially. The pruning varied somewhat with the variety. An attempt was made to develop a strong, balanced scaffold system to prevent severe wind damage and to permit the maturity of a normal crop of fruit without propping. For some varieties, thinning was required in most years. With the varieties well interplanted, and weather at blossom time usually favorable for insect activity, conditions for pollination were good. An occasional dormant lime sulfur spray was applied for control of scale.

The first planting was made in 1930, and subsequently new varieties were added until at present the orchard includes the following: Agen (French Petite), Apex; B. B. —18; B. B. —16 East Branch; Beauty; Blood X; Bradshaw; Burbank; Climax; Coates; Delicious; Diamond; Duarte; Elephant Heart; Elliot; Formosa; German Prune; Giant American; Giant Oxheart; Great Yellow; Imperial; June Blood; June Redskin; Mammoth Cardinal; Mammoth French; Mariposa; O. 12 E. T.; Orange Plumcot; President; Purple Plumcot; Red Rosa; Santa Rosa; Satsuma; Sugar Prune; Tragedy; Vacaville; Weather-spoon; and Wickson.

#### TYPE AND SEASON OF PLUMS DESIRED

Of the 1,049,634 plum and prune trees reported in Washington for 1936, about 95 per cent were of the Italian variety, about 2 per cent were other varieties of prunes, and about 3 per cent were listed as plums (2). The harvest period for the Italian in any one section is usually not more than 2 weeks. This short season does not favor efficient use of labor and equipment necessary to harvest, pack, and ship plums. Since plums can be retained only relatively short periods of time in cold storage, they must often be placed on congested markets. Furthermore, in marketing, prices fall rapidly from anticipation and receipt of a large supply of plums. By growing other plum varieties that would extend the market period and supply the product according to the demand, higher prices might be maintained.

New varieties should be attractive as a fresh fruit, ripen during a different period than that of the Italian, have a relatively long harvest season, keep well in temporary storage, and withstand packaging and distant shipments.

*Blossoming Dates:*—The plum varieties have been divided into three groups according to their blossoming dates: early; mid-season; and

TABLE II—THE RIPENING DATES\* DURING 1932, 1934, 1935, 1936, 1937, AND 1938 OF THE PLUM VARIETIES IN THE TRIAL ORCHARD, IRRIGATION BRANCH EXPERIMENT STATION

Variety	Dates Harvested					
	1932	1934	1935	1936	1937	1938
Agen (French Petite)						
Apex	July 6 to 15	August 16 to 18	July 5	August 25	September 8	September 10
B.B. 16 East Branch			August 9	June 30	July 12	July 6
B.B. 18			August 8	August 1	August 18	August 10
Beauty				August 1	August 18	August 14
Blood X	July 16 to 25			July 8	July 24	July 11
Bradshaw		July 6 to 10	August 9	August 1	August 18	August 12
Burbank	August 12 to 25	July 27 to 30	August 9	July 15	August 2	July 30
Climax	July 20 to 31		August 5	July 19	August 27	August 25
Delicious			August 6	July 29	July 18	July 29
Diamond	August 5 to 15			August 17	August 10	August 10
Duarte		August 12 to 20	August 24	August 20	August 27	August 25
Elephant Heart			September 6	August 20	October 1	October 10
Elliott			August 24		September 8	September 12
Formosa					July 31	July 29
Giant American	August 1 to 6		August 6	July 15	August 8	August 16
Great Yellow Plum			July 25	July 18	August 31	August 5
Giant Onheart			August 7	July 18	August 4	August 6
Imperial Epineuse		August 12 to 13	September 1	August 28	September 8	September 9
June Blood			July 8		July 21	July 11
June Redskin				August 2	August 6	August 5
Mammoth			August 28	July 21	July 31	August 29
Mammoth French		August 10 to 14	August 7	August 24	September 8	September 10
O. 12 E. T.				July 28	August 18	August 18
Orange Plumcot				July 28	August 27	August 20
Prairie	September 5 to 20	August 8 to 12	October 2	September 16	October 1	September 24
Santa Rosa	August 1 to 10	July 7 to 12	July 31	July 10	August 2	August 5
Sugar Prune		July 6 to 20	August 6	August 16	No fruit	August 20
Vergennes		July 6 to 10	August 25	July 15	August 2	August 20
Wickson	Aug. 20 to Sept. 5	July 18 to 25	August 6	August 18	August 27	September 8

\*Under comparable conditions the average ripening period of the Italian would approximate from August 22 to 28.

late blooming. June Blood, Beauty, Formosa, Climax, Mammoth Cardinal, June Redskin, Santa Rosa, Burbank and Wickson are early blooming varieties that are likely to be injured by late spring frosts. In 1937 the period of first to full bloom for this group of varieties was from April 7 to April 12 and in 1938 it was from April 1 to April 8. Many of this group also have a short blossoming period, necessitating care in selecting a variety that blossoms at approximately the same time to provide for cross-pollination. This would be required since these early blooming sorts are essentially of Japanese origin (*Prunus salicina*) and thus largely self-sterile.

Apex, Great Yellow, Giant American, Delicious, B. B. 16 East Branch, Blood X, O. 12 E. T., B. B. 18, Duarte, Orange Plumcot, and Elephant Heart are mid-season blooming varieties. In 1937 the period of first to full bloom for this crop was from April 10 to April 18 and in 1938 it was from April 3 to April 11. These are also mostly Japanese varieties, and although they are not so subject to spring frosts, their length of blossoming period is short and their pollination requirements, therefore, comparable to the varieties of the early blooming group.

Vacaville, Bradshaw, Diamond, Agen (French Petite), Mammoth French, Imperial, President, Elliot, Italian and Sugar Prune are late blooming varieties of the European type (*Prunus domestica*). In 1937 the period of first to full bloom for this group was from April 13 to April 26 and in 1938 it was from April 9 to April 19.

These varieties usually escape late spring frosts. They have a relatively long blossoming period, which favors cross-pollination, and they are not so likely to be self-sterile as are varieties of Japanese origin.

*Ripening Dates and Harvest Notes:*—The ripening dates indicated in Table II show rather wide variations from year to year although the sequence is about the same. Apparently no relation exists between the blossoming and ripening dates. The plums were picked somewhat riper than would be practiced commercially. In most instances they approached a firm tree ripe condition.

#### RECOMMENDED VARIETY

The *President*:—A European plum that produces a tall, upright, vigorous, winter hardy, medium sized tree that is a regular, heavy bearer. Its late blooming habit lessens the danger of injury by spring frosts and its late ripening period extends the plum season well beyond that of the Italian. Although the limbs develop acute angles and grow upright it apparently forms a strong scaffold system. Fruit spurs are borne on 2-year-old growth. Uniformity of the age and size of the fruiting wood tends to favor uniformity of growth and ripening of fruit.

The fruit is oblong, large sized, purple in color, but is given a bluish tint by the heavy bloom. The skin is relatively thick and tough, making the fruit resistant to bruises and punctures. The flesh is light yellow, firm, sub-acid, freestone, and of good quality. The fruit maintains its optimum condition of harvest maturity for a long period of time.

#### PROMISING VARIETIES

*Santa Rosa*:—A Japanese plum that has gained popularity in some sections. The tree makes an upright growth until it comes into production and then gradually becomes more open and spreading. The

crotches of the scaffold limbs form narrow angles, yet seem able to support fruit and resist wind damage. The tree is medium sized and vigorous, and not subject to winter injury or to diseases.

The fruit is comparatively uniform in size and shape, but ripens rather unevenly over a long period of time. It is dark red when ripe, medium to large, heart-shaped with a prominent apex, clingstone, and covered with a heavy bloom. The skin is somewhat tender, flesh yellow, tinged with red, juicy, sweet, firm, fine textured, and of good quality. This plum ripens earlier than the Italian. Its limitations are its uneven ripening habit, and a tendency to produce light crops.

*Beauty*.—A Japanese plum of possible value by reason of its early ripening habits. The tree is small to medium sized, spreading, and open. It is not especially vigorous as indicated by short terminal growth and small leaf size. The wood is brittle and breaks easily when loaded if not propped carefully, and is somewhat subject to winter injury. This variety bears heavily and usually requires thinning.

The fruit is medium sized, round, slightly pointed at the apex, dark red, and covered with a grayish bloom and prominent white lenticels. The flesh is dark red, firm, sweet, and of good quality. Although uniform in size and color, the fruit ripens unevenly on the tree.

*Elephant Heart*.—A Japanese hybrid which produces a moderately vigorous, relatively winter hardy tree that is tall, upright and narrow, with branches developing at acute angles. Growth is usually made from the terminal buds and only occasionally from lateral buds, which gives the tree its upright character with few side branches. The fruit spurs are located on the upright branches.

The very large fruit is dark red, heart-shaped, and dotted with numerous large yellow lenticels partially obscured by a sticky, dull, waxy finish. The skin is thick and resistant to bruising and punctures. The flesh is firm, deep red, semi-clingstone, sweet, aromatic, of excellent quality, and retains its optimum condition of harvest maturity for a long period of time. It is the last of the Japanese sorts to ripen, usually during the latter part of September.

Its narrow upright growth and uneven bearing habit are its limiting factors. With proper pruning, however, this might be overcome.

*Imperial Epincuse*.—A European plum that has found favor in California. The tree is vigorous, medium sized, open and spreading, and supports an abundant load of light green foliage. The limbs form wide, obtuse angles that facilitate the support of large crops of fruit. Growth is largely made from terminal buds and side branch development is limited, which gives the tree its open appearance.

The fruit is medium size, oblong, pyriform, sides flattened, with a round apex and tapering to a short neck toward the stem end. The fruit is bluish red in color and covered with a moderately heavy bloom, and thin but tender skin. The flesh is light yellow, very sweet, freestone, and of excellent quality.

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# The Effect of Root-Knot Upon the Subsequent Growth of Tung-Oil (*Aleurites fordii*) Seedlings

By R. D. DICKEY and HAROLD MOWRY, *University of Florida, Gainesville, Fla.*

**L**OSSES caused by root-knot in the Southern States are so severe that it is often said to be the most important single plant pest in that area. The host range of the parasite (*Heterodera marioni*) producing this disease is quite large and includes among its number some of the most important crops grown within its range of distribution.

Newell (1) states that tung-oil nursery trees (*Aleurites fordii*) affected with root-knot were observed for the first time on February 24, 1923, at the Experiment Station at Gainesville. This condition was found to be most prevalent on trees grown on old cultivated land. Young seedlings so attacked failed to make a normal growth while, in other cases, they have been apparently killed. Furthermore, it was observed that this trouble did not show up where the seed had been planted in new land or in land which had been in grass for one or two seasons.

The need for information relative to the effect of root-knot upon the subsequent growth under field conditions of infested seedlings led to the experiment reported below.

## EXPERIMENTAL STUDIES

In January, 1932, severely affected seedlings of trees No. 2 and 9 (these are the trees referred to in Table II of Florida Agricultural Experiment Station Bulletins 221 and 280) of the original 10 trees on the Experiment Station grounds were planted in the field (Fig. 1). The trees used in this experiment were selected from a large group of infested seedlings and were chosen particularly for the severity of attack by the root-knot nematode. Hills, 1, 4, 5, 10, 11, 14, 15, 18, and 19 of this row were seedlings of tree 2; hills 2, 3, 6, 7, 8, 9, 12, 13, 16, and 17 were seedlings of tree 9. This row was planted adjacent to a block which was being given the care recommended by the Station for commercial plantings, and was treated in exactly the same manner.

Tree 2 is the type tree of the Florida variety (cluster type) and tree 9, though bearing its fruit singly, is of considerable merit because it has outborne tree 2.

In February, 1936, all of the trees remaining alive, except two, were removed from the soil and the root systems carefully examined. In order to determine the condition of the root systems of the remaining two trees, as regards root-knot injury, the soil was removed from around their crown and trunk. When this had been done the soil was replaced. One of the trees dug still showed some evidence of the previous root-knot injury and was replanted. It was re-dug in December, 1938.

## RESULTS AND DISCUSSION

The data presented in Table I show that, during the 4 years intervening from the time of planting until digging, eight of the 19 trees had

TABLE I—THE NUMBER OF TUNG-OIL SEEDLINGS AFFECTED WITH ROOT-KNOT ALIVE, FEBRUARY, 1936 (PLANTED IN JANUARY, 1932)

Number Trees Dead		Number Trees Alive		Total	
Tree No. 2	Tree No. 9	Tree No. 2	Tree No. 9	Dead	Alive
5	3	4	7	8	11

died. Of these, five were No. 2 seedlings and three were No. 9 seedlings.

The extreme vigor of growth of the parent No. 9 tree has been pointed out by Newell *et al.* (2, 3). Observations of field plantings of seedlings of this tree have further substantiated this point, which suggests that the greater "live" of seedlings of this parentage may be due to their decided growth vigor.

At the time of digging, a thorough examination of the root systems of the 11 trees which were still alive revealed that all trace of the root-knot injury shown in Fig. 1 had completely disappeared (Fig. 2) from all except one tree, which still showed some slight evidence of the previous infestation. This tree was replanted and, when taken up in

December, 1938, it was found that all signs of root-knot injury had disappeared.

Watson and Goff (4) state that the culture of perennial plants in root-knot infested regions is complicated by the long life of these plants, subjecting them to infestation over a long period of time. Several fruit trees, particularly peaches and figs, and several ornamental plants such as *Pittosporum Tobira*, *Ligustrum japonicum* (*L. lucidum*), roses on certain rootstocks and *Gardenia jasminoides* are severely attacked in Florida when planted upon infested soils.

Since this is true, it is of considerable importance to know what will be the result, under field conditions, of planting tung trees upon heavily infested soils, particularly in view of the fact that,



FIG. 1. Seedlings of tree No. 2 badly infested with the root-knot nematode. Planted in the field January, 1932.



under certain conditions, seedlings during their first year of growth are quite susceptible to attack.

In this regard it is to be noted that an examination of the root systems of the trees previously referred to showed that they had completely grown out of the root-knot symptoms evidenced at the time of planting and that no further infestation had taken place (Fig. 2), this despite the fact that the roots of these trees are growing in soil heavily infested with the root-knot nematode, which was shown by the fact that okra planted close to these trees became heavily infested in a few weeks time.

Furthermore, the writers have from time to time examined the root systems of numerous tung trees which have unquestionably been growing in soil that is heavily infested with the root-knot nematode. These trees have ranged from 1 to 18 years of age. Except in a few isolated cases, no galls have been found upon their roots. In the few cases in question, one or two small galls were found but were of such a nature that it was impossible to attribute them definitely to this cause.

It is clearly indicated that tung-oil seedlings are highly susceptible to attack by the root-knot nematode their first growing year in the nursery whereas these same seedlings, when planted in the field at 1 year of age or older, are apparently quite resistant, if not immune. Furthermore, severely affected seedlings, when planted in the field, show no further infestation and eventually grow out of any evidence of the previous infestation, as far as the root system is concerned.

The effect of the nematode root-knot attack has been such as to weaken the vigor of the seedling trees and subsequent exposure to low temperatures resulted eventually in the death of 8 of the 19 trees. Also, nursery stock which has become stunted from any cause will ordinarily fail to grow into vigorous field trees and for that reason should not be planted. This was true for those trees which remained alive because they were much smaller at the end of their fourth and seventh growing years in the field than were near-by trees of the same age and parentage which came from vigorous nursery stock that was free of the disease.

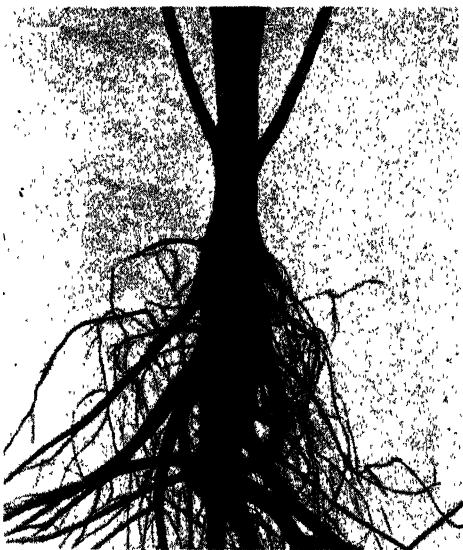


FIG. 2. Appearance of seedling of tree No. 2, when dug February, 1936. When planted this tree was in a condition similar to that shown in Fig. 1.

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# The Problem of Nomenclature Under Present-Day Conditions

By M. J. DORSEY, *University of Illinois, Urbana, Ill.*

THE early efforts to formulate a system of nomenclature in horticulture followed and were in part patterned after a similar movement in botany. From the very beginning, the discussions centered around synonyms — which is the very basis of a permanent system of variety units. At Philadelphia, December 13 to 14, 1852, provision was made for a “standing” committee on synonyms. Some of the men prominent in the discussions on nomenclature were: Patrick Barry, John A. Warder, Charles Downing, C. M. Hovey, George Hussman, Dr. William Howsley (who read the first paper on “Nomenclature of Apples” in 1871 in Richmond, Virginia), Marshal Wilder, W. J. Beal, T. T. Lyon, Robert Manning, W. H. Ragan (who made most extensive studies with both the apple and pear from the United States Department of Agriculture), William A. Taylor, E. R. Lake, L. H. Bailey, U. P. Hedrick, C. P. Close, and H. P. Gould.

## OBJECTIVES IN A CODE OF NOMENCLATURE

The code of the American Pomological Society “aims to establish a simple system of nomenclature with the cultivated fruits and nuts which is appropriate and stable”. While the right of the “originator, discoverer or introducer” of a new variety to name it is recognized, the code urges all persons who may be naming varieties to select “simple and preferably one-word names” which are “fittingly expressive of some character, quality, place, person or event” associated with its origin. The name “first published” for a variety will “be accepted and recognized”, provided it does not displace a well established name for another variety or violate some provision in the Code. Obviously, the observance of this principle would avoid much confusion, but common usage must be reckoned with. For that reason provision was made in the Code for the establishment of a variety name by usage on a par with publication. This is a very important consideration and it has taken a great deal of research, in some instances, to determine which is the correct name for a variety. In order to draw the line sharply between usage and publication, the latter term has been defined as “distributing to the public a name in printed form, accompanied by a recognizable description or illustration”. Even then “a name established by current usage is given precedence over a later printed name for the same variety”.

Certain details in the form and spelling of names are set forth in the Code. While a one-word name is preferred, a two-word name will be accepted. In the light of the extensive use made of superlatives in modern advertising, it can be seen that this feature will suffer many departures. The “spelling and pronunciation” of a variety name should be the same as that of the “person, place, substance or quality” from which it was derived. The possessive noun and hyphenating two or more names should be avoided. For the sake of simplicity and brevity

the use of initials, titles and such general terms as hybrid, seedling, pippin, rare-ripe, etc. is discouraged, although, even in these, common usage has often gotten out of control and violated some provision of the code. When a variety is introduced from another country, its foreign name should be retained, although it may be translated into its English equivalent if some provision of the code or an existing name permits it. One can easily picture many complications in this direction and considerable discussion was given to this point at the Twelfth International Congress at Berlin in August, 1938. Other items in this phase of the problem might be mentioned but these will suffice to indicate the direction of the recommendations and how difficult it will be to follow even these simple rules in all cases.

Horticultural varieties vary when grown under a wide range of conditions, or in different sections of the country, and so, in the early discussions on nomenclature, horticulturists followed the lead of botanists and placed considerable emphasis upon the variety type. It was insisted that type descriptions or illustrations should be made of the original plant, if available. It has since been pointed out that sometimes the original plant in seedling progenies may be so crowded that it was not making a "normal growth"; consequently, provision has been made to recognize descriptions from plants propagated asexually from the original when grown "preferably in the same pomological region". It has been urged that type descriptions include the characteristics of the plant, foliage, flowers, fruit and season—in other words, complete enough to distinguish the new variety from all others of "similar appearance".

It will be evident from this brief summary that much thought has been put upon the problem by the "founding fathers". Little would be left to do if all of these provisions were adhered to strictly. But under present-day conditions still other phases of the problem come to the fore. Let us now consider some of these very briefly.

#### BUD SPORTS

One of the first things the present committee had to deal with was that presented by the color sports of the more important commercial varieties. These did not arise just occasionally, but within a decade or so, they have come to the fore by the hundreds, and they are still coming. In one variety alone, Delicious, the last list which made any claims at completeness, totaled 80 or so. But somatic mutations are not limited to color alone; sports affecting size, season, vigor, yield, and so on began to appear. In fact, viewed in its larger aspects in horticulture as a whole, bud sports are actually challenging other methods of genetic technique as a means of variety improvement. And the end is not in sight, for we are now getting sports from sports. You can see how this new development began to affect variety names, because there is an opportunity to give every one of these new bud sports a name. If only the color of a variety is affected, say deepened by the sport, one can easily picture virtually the same "plant entity" or variety coming on the market under any number of different names. Since this would lead to endless confusion, the committee on nomenclature took the

position that "in naming the bud sports of recognized varieties, the names selected should, as far as possible, identify the new strain with the parent variety". The fundamental reason for this will be made more clear a little later.

#### RECOGNIZING USAGE

Earlier in this paper stress was placed upon usage as a factor in variety names. We all recognize the power of usage in the growth of a language. In plants, names are coined by common people who come to know plants or fruits as they must in making a living from them. Even though there is some duplication and confusion in the common names of plants and varieties, they are as stable as the scientific names. Hence, the code provides that "where there is a long-standing and well established trend in the use of a name", which, according to the code, is a "synonym", the situation may be reviewed and where "justified" the name thus established may be recognized as the correct name. Instances to illustrate the point come to mind in Duchess versus Oldenburg, Albermarle Pippin and Newtown Pippin, Steel's Red versus Canada Red. It would only be fair to state, however, that there is not complete agreement on this point among pomologists.

#### RENAMING FOR TRADE PURPOSES

Closely akin to this problem is the tendency to rename new varieties, when a "sales campaign" is started, if the accepted name according to the priority rule may, for one reason or another, be lacking in "appeal". In the interest of permanence and stability the code declares this unethical. On this point, however, there would also certainly be some disagreement. The problem needs further study. Some think the name has little to do with the way a variety "goes across". Others place a lot of emphasis upon a good name. The code looks to the future on this point. Much can be gained at the outset in selecting a suitable name for the new varieties and at the same time much effort would be saved by a more thorough test and study of all new offerings before they are introduced. This procedure may result in not even naming some things which might otherwise be "introduced".

#### VARIETIES UNDER TEST

In line with the above, provision has been made in the code to hold "seedling selections" in breeding investigations under "number, letter, code term", or any other tentative term, during the trial period before introduction, without such designation being given priority.

#### THE LARGER PROBLEM

With the ground thus cleared, we can now pass on to still broader phases of the problem of nomenclature. It will be recognized from what has been said that it is very desirable for variety names to be simple, stable, appropriate, and universally accepted. That is, there should be no synonyms in the future if we profit by our experience. But look for a moment at some of the present trends, such as the narrowing down of the commercial variety list, the power of advertising, the inter-

national situation, the United States grades, the closed package regulations, the truck versus the railroads, the interfruit competition, the concentrated production areas, "long hauls", the immense storage houses in the big city centers, the power of the big buying units and all that. Then, too, there is great interest in the development with frozen fruits, canned and dried products and fruit juices. In the market it is found that women buy the larger part of the fruit products, as high as 80 per cent in some cases. Styles in packages have changed over the past century from the basement, the bin, the barrel, the basket to the box and now back to the bin and bag in chain store sales. This is the American "B" line.

Come now to the breeding plots, the nursery, the orchard, the packing shed, the market and then into the kitchen. What is demanded of variety names in this very complex background which characterizes the commercial era of our day? Greater and greater emphasis lies ahead in the direction of keeping varieties true to name. This is the trend in all industry, and fruits will inevitably fall in line as buying becomes more specific and intelligent either for special uses or in larger quantities. This will tend to force greater care in keeping horticultural materials true to type and name all along the line. If this is to be accomplished, it may call for some sort of a system of certification from the nursery to the grower, if the grower in turn is to be able to certify his shipments correctly to the trade. The dealer must also keep in line—and this is most important of all—if the industry is to take full advantage of the repeat orders which come from intelligent and informed consumer buying.

Horticulture is thus seen to be "growing up". Variety names are assuming the same status in industry as other commodity names, some of them are produced in large quantities, advertised, known to the consumer and adapted to special uses. But there are two things in the situation just now which need study. One is the use made of brand names and the other is the tendency to tack on "riders" to the better known variety names, making them in reality group names. Let us consider these two items briefly, keeping in mind the relationship between "repeat orders" and informed consumer buying and also the fusillade of today's advertising in all lines. In our own field it is apple week, clipping sheets, billboards, roadside markets and advertisements in magazines. Sometimes emphasis is placed upon iron, at other times upon vitamins, but always upon health.

To illustrate the first point let us take Elberta. It is by all odds our best known peach. It would take time and money to put another variety across to the same extent. So in some of the later offerings we have Early Elberta, June Elberta, July Elberta, Redelberta, Halberta, and perhaps still others. There is a similar tendency with some other varieties: Early McIntosh, Sweet McIntosh, Black Mac, and so on. While it is true that emphasis has been placed upon keeping the color sports lined up with the parent variety, there is clearly a limit to the number of names the trade and the consumer can absorb. For that reason this phase of the nomenclature problem needs study, and perhaps some guidance.

The use of brand names makes it still more difficult for the public to understand varieties. Many people are confused as to the difference between the name of a variety and a brand. In order to buy intelligently, all that the consumer needs to know is the variety. It is true that the grade, brand, size, grower, and region all give further information about the variety. Of course, the brand is a device which enables the advertising to focus the attention of the public upon the product of a particular region or firm and, as generally used, is also a guarantee of quality or grade. But the variety name and the qualities of the variety are the essential things. There will, of course, be much difference of opinion upon this point but we should consider the matter carefully from the standpoint of stability in variety names.

From what has been said thus far, most will agree that some agency should be at work on the broader aspects of the nomenclature problem. Certainly with the emphasis placed upon a plant entity in the Plant Patent Act, the necessity of keeping the name identified with the entity will be apparent. Up to the present, nomenclature has been fairly well taken care of by the more specialized societies interested in the different crops, but the task has in many respects gone beyond the capacity of a society, a secretary, or a committee on nomenclature. There are records and permanent files which should be kept. Research, by a trained staff of adequate proportions, is needed. The problem has broadened from local or state lines to regional, national and even international proportions.

This has all taken place since 1852, when horticulturists in this country first began to think about avoiding confusion through correct nomenclature, but what about the next 86 years? That is the question which now confronts us and to that end it is proposed that a Registration System be established for all new varieties. The scope of the task, to say nothing of the time element, would require that this service be placed in the United States Department of Agriculture, and President B. S. Pickett, of the American Pomological Society, has already suggested this procedure to the proper authorities. The whole problem is extremely complex and involved, and for that reason it needs study and guidance. It may be of interest to know that from the legal angle the whole problem of variety substitution and renaming comes under the jurisdiction of the Federal Trade Commission.

In closing it need only be added that pomologists think it more necessary, today, than ever before, to insist upon the variety as the unit in horticulture. In the cycle from the breeding plot, through the nursery, to the orchard, then in transit and in the market, and finally to the kitchen, there is no other alternative in organized industry than to keep the variety constantly before the consumer.

## Further Results on the Influence of Branch Ringing on Fruit Set and Size

By A. E. MURNEEK, *University of Missouri, Columbia, Mo.*<sup>1</sup>

IN a preceding report (1) some preliminary results were presented on the effects of branch ringing on fruit set of Minkler and Arkansas varieties of apples. The remarkably increased setting was attributed to the influence of the treatment on the various drops of immature apples. The present paper gives additional evidence on the effects of branch ringing on fruit set and size in other varieties of apples.

The growing season of 1938, during which this study was performed, was characterized at Columbia, Missouri, by a killing frost at the time when most varieties of apples were in flower. Hence only a few late bloomers, that escaped serious and complete injury, were available for the investigation. The material was limited almost entirely to the Rome, King David, Ingram and Ralls varieties, of which the Rome was used most extensively.

On selected trees a number of large branches were paired, one being used for treatment, the other left as control. As in the preceding year, the branches were ringed by removing a strip of bark  $\frac{1}{4}$  inch wide and covering the wound with grafting wax. The healing of the rings was prompt and satisfactory. Not a single branch seemed to have been permanently injured by the treatment.

To test the effects of early, late and very late ringing, the work was performed at three periods: when the trees were in full bloom, 2 weeks later (Rome only), and 10 weeks later. Since the last period of ringing occurred after the final normal drop, its effect on fruit size only could be measured. In all other instances the fruit set was determined at fairly close intervals. The results are presented in Tables I and II.

It is evident (Table I) that though ringing increased the setting of fruit from the very beginning (Ingram a possible exception), this improvement was augmented throughout the time of the second, third and fourth drops (2). In fact, the early stimulation from the treatment was slight at first in the case of King David variety and none at all (actually a possible decrease) in Ingram. The final increased set due to ringing of over 30 per cent in Ingram and King David and over 90 per cent in Rome is conspicuous indeed. Evidently this treatment improved remarkably the nutritional condition of the fruit. No change, however, was brought about in the number of fully developed seeds, which is in agreement with previous results (1).

While the set was enhanced strikingly by branch ringing, there was likewise an appreciable increase in size of the fruit (Table II). This is the more notable, as the ringed branches carried a 30 to 90 per cent greater load of fruit and no adjustment was made for a uniform leaf to fruit ratio. The temporary damming up above the ring of carbohydrates (3) and other food materials undoubtedly was of benefit to the

<sup>1</sup>Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station Journal Series No. 600.



TABLE I—EFFECTS OF BRANCH RINGING ON FRUIT SET

Treatment	Number of Flowers Involved	May 7 (Per Cent Set)	May 14 (Per Cent Set)	May 21 (Per Cent Set)	May 31 (Per Cent Set)	June 8 (Per Cent Set)
<i>Rome</i>						
Branches ringed on April 14 (full bloom)						
Ringed . . . . .	18,702	22.5	16.7	14.1	13.2	13.0
Not ringed . . . . .	20,022	17.4	10.6	7.7	6.9	6.7
Increase due to ringing %	—	+29.3	+38.1	+83.1	+91.3	+94.0
Branches ringed on April 30						
Ringed . . . . .	13,940	15.8	11.5	10.4	9.4	9.2
Not ringed . . . . .	16,636	12.4	7.2	5.4	4.9	4.8
Increase due to ringing %	—	+27.4	+59.8	+92.6	+91.9	+91.6
<i>Ingram</i>						
		May 10	May 17	May 27	June 4	June 14
Branches ringed on April 19 (full bloom)						
Ringed . . . . .	8,439	21.8	15.8	12.9	13.3	10.7
Not ringed . . . . .	8,623	22.1	16.7	11.9	8.5	8.0
Increase due to ringing %	—	-1.4	-5.4	+8.4	+32.9	+33.7
<i>King David</i>						
		April 30	May 5	May 17	May 27	
Branches ringed on April 12 (full bloom)						
Ringed . . . . .	8,254	24.2	14.1	11.0	10.4	—
Not ringed . . . . .	8,884	23.5	12.2	8.0	7.9	—
Increase due to ringing %	—	+ 3.0	+15.6	+37.5	+31.6	—

TABLE II—EFFECTS OF BRANCH RINGING ON FRUIT SIZE

Treatment	Ringed in Full Bloom		Ringed 10 Weeks Later	
	Weight of Fruit (Gms)	Increase Over Controls (Per Cent)	Weight of Fruit (Gms)	Increase Over Controls (Per Cent)
<i>Rome</i>				
Ringed . . . . .	108.2	+12.7	113.6	+13.9
Not ringed . . . . .	96.0	—	99.7	—
<i>King David</i>				
Ringed . . . . .	88.1	+10.1	99.2	+16.3
Not ringed . . . . .	80.0	—	85.3	—
<i>Ingram</i>				
Ringed . . . . .	74.0	+10.3	72.2	+5.1
Not ringed . . . . .	67.1	—	68.7	—
<i>Ralls</i>				
Ringed . . . . .	—	—	115.9	+18.4
Not ringed . . . . .	—	—	97.9	—

fruit not only in setting but also in their growth. That the carbohydrates may have played the predominant role in this situation is evidenced by the fact that when branches were ringed as late as 10 weeks after flowering, the increase in size of fruit was just as great as that obtained from early ringling.

In its first stages of development the apple seems to absorb most of the nitrogen and other soil nutrients, while its subsequent growth and final size evidently is determined mainly by the moisture and car-

bohydrate supply. By adjustment to a desirable relationship of the fruit to foliage and by branch ringing, one can regulate the carbohydrate supply to the fruit and thereby its size.

In general then, it is apparent from this and related investigations that branch ringing, executed at the proper time, increases the set and size of apples.

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## Parthenocarpy in the Fig

By IRA J. CONDIT, *University of California, Riverside, Calif.*

THE term "parthenocarpy" was defined by Noll (6) in 1902 as "the capacity of many plants, under exclusion of pollen, to form fruits, outwardly normal, but in which seeds are absent or aborted." There are, however, some seedless fruits for the production of which pollination is necessary, but in which fecundation is either not affected or there is subsequent embryo abortion. In an unpublished seminar paper, therefore, P. D. Caldis<sup>1</sup> suggested the modified definition: "Parthenocarpy is the capacity of many plants to form fruits outwardly normal but in which seeds are absent or aborted." The word "aborted" here is understood to include sterility as sometimes exhibited in the tobacco and fig, the "seeds" being outwardly normal but devoid of embryo or endosperm. Goodspeed (3) has applied the term "phenospermy" to this type of parthenocarpy in tobacco. I have used (1) the term "cenocarpy" to denote the production of an achene (as found in the fig) which has a normally developed ovary wall but which does not contain an embryo.

Vegetative parthenocarpy as described by Winkler (10) has probably been recognized as a characteristic of the fig almost from the beginning of the use of this fruit as a human food. Furthermore, this characteristic forms, in part, the basis for the classification of figs into four different groups or types: namely, caprifigs, Smyrna figs, White San Pedro figs, and common figs. It is my purpose to discuss here each of these four types of figs in relation to their development by parthenocarpy.

The caprifig type includes those figs whose syconia or receptacles commonly produce both staminate and pistillate flowers, the latter being short-styled and thus adapted to oviposition by the blastophaga. Ordinarily the stimulus of oviposition with the consequent development of larvae in the short-styled gall flowers is required to bring about setting of caprifigs and their development to maturity. Some caprifigs are, however, partly parthenocarpic and produce polleniferous or "blank" figs more or less freely, as pointed out by Schwarz (7), Eisen (2), and others. One variety, Roeding No. 1, is especially well known in California as a producer of polleniferous figs. Often these are outwardly indistinguishable from the "insectiferous" figs on the same tree until they reach a rather late stage of maturity. The polleniferous figs of Roeding No. 1 are hollow within, devoid of insect galls, and pinkish in color around the undeveloped flowers; the "insectiferous" figs are filled with plump, achene-like galls and the flower stalks are colored violet-purple. Each of these two types of figs has a well-developed mass of staminate flowers within the eye and each produces pollen profusely.

There is a distinct variety of the caprifig type which is completely parthenocarpic or nearly so. In Europe it is designated as the Croisic, from the name of a town on the coast of Brittany near which were

<sup>1</sup>From an unpublished seminar paper by P. D. Caldis, Davis, November 23, 1925.

grown the specimens described by Count Solms-Laubach in 1882 (8). Since the fruit had staminate flowers occupying the same place and distribution as in the profichi of the caprifig, Solms-Laubach considered it as only a highly developed caprifig which became edible.

Figs similar to the Croisic have been found in various parts of France. Dr. L. Trabut (9) described such a variety cultivated at Angers, and Leclerc du Sablon (5) found, in various places, figs having short-styled flowers and stamens but becoming fleshy and edible. The latter concluded that the Croisic is simply a caprifig cultivated in a country where the blastophaga does not exist, the fruit developing by parthenocarp and becoming edible. The Saint John fig grown in England since about 1890 is apparently the same as the Croisic.

In July, 1893, Gustav Eisen (2) found on the San Francisco market some edible fresh figs which showed beneath the ostium numerous male flowers with "abundant perfectly developed pollen". He named it Cordelia but concluded that "it is not impossible that this fig is identical with the Croisic described by Solms-Laubach". The Cordelia is fairly common in central California where in May the tree has the appearance of a prolific caprifig. In June, however, the figs become soft, pulpy, and worthless either for caprification or for the fresh fruit market. In the cool climate of the San Francisco Bay region, on the other hand, the Cordelia is practically certain to mature a good breba or first crop and often matures a second crop, both developing by parthenocarp. It is also being grown commercially to a small extent near Portland, Oregon. Two seedling caprifigs which are completely parthenocarpic have recently been found among several hundred others in our seedling fig plots at Riverside, California. It is evident, therefore, that while most caprifigs are non-parthenocarpic, some are partially parthenocarpic and a few completely so.

Figs of the Smyrna type are almost completely non-parthenocarpic. Structurally the flowers are apparently identical with those of various common figs. Yet syconia of the Smyrna type mature only after "the pollination of their long-styled flowers and a resultant development of the ovaries into achenes. Without such stimuli the immature figs of both the breba and the main crop usually shrivel and drop when about an inch in diameter. Sometimes a few brebas develop parthenocarpically" (1). Eisen (2) has called attention to the fact that a few of the first-crop Smyrna-type figs became half-ripened, that is, yellow and soft, but insipid. According to Hagan (4), the name "Yel Injur" is used in Smyrna, Asia Minor, to designate an early crop of figs that matures in June in some seasons. With the development of extensive Calimyrna orchards in the San Joaquin Valley, California, growers sometimes find these yellow brebas in sufficient quantities to warrant shipping them to the fresh-fruit market. It may be stated, therefore, that parthenocarp is found in Calimyrna brebas but very incompletely so.

Trees of the White San Pedro type of fig show a very peculiar and exceedingly interesting behavior as to fruit production. As in all figs, fruit buds appear in the axils of leaves during late summer or fall and

remain on the twigs during the winter in a dormant condition. In the spring, the San Pedro fruit buds enlarge and grow along with the vegetative shoots and leaves and reach pomological maturity in June. In other words they show complete parthenocarpic development. In the axils of the current crop of leaves on the same twig there appear in summer other fruit buds which are of the Smyrna type; that is, their flowers require the stimuli of fecundation and embryo development to bring about fruit maturity. Here is a case of both parthenocarp and non-parthenocarp on the same branch in the same growing season. The White San Pedro, Gentile, Ronde Violette Hative or Dauphine, Lampeira of Portugal, and other varieties of this type are apparently Smyrna-type figs in which parthenocarp is present in the first crop only.

The fourth class, the common type, includes figs such as Mission, Kadota, and Brown Turkey, which are completely parthenocarpic under the environmental conditions best suited to their culture. Most common figs have complete parthenocarpic development of figs in one crop, and many varieties produce two crops parthenocarpically in a single growing season. While complete parthenocarpic development is characteristic of the best common figs, these require the proper environmental complex for the full expression of parthenocarp. For example, the Brunswick (Magnolia) tree is vigorous in growth, and the figs are completely parthenocarpic or nearly so in humid parts of Texas. In the dry climate of California, however, the trees lack vigor and the figs are incompletely parthenocarpic, a considerable percentage of the figs shrivelling and dropping long before they reach full size or maturity. The factor for parthenocarp, therefore, appears to be rather unstable or only incompletely fixed in some common figs.

The designation by Eisen (2) of common fig flowers as "mule flowers" and incapable of fecundation has been found to be incorrect. No common-type fig has yet been found which cannot produce fertile achenes if the flowers have been pollinated and fecundated.

The inheritance of parthenocarp or of non-parthenocarp has received little attention. All work on fig breeding up to the present time indicates that the character Smyrna-type is a dominant one in most if not all Smyrna-type figs and in all forms of the two species *Ficus pseudocarpa* Miq. and *F. palmata* Forsk.

In a very few years we expect to have data which will shed more light on this matter of inheritance in figs. For example, in the seedling fig plots at the Citrus Experiment Station, there are about 1,000 seedlings of Calimyrna (many already fruiting) crossed with 10 different varieties of caprifig; over 1,600 seedlings 1-year-old from crosses involving 14 varieties of parthenocarpic figs and one caprifig, Roeding No. 1; and barring accidents there will be next spring over a thousand seedlings of 12 common figs crossed with pollen of the two completely parthenocarpic caprifigs already mentioned. The Calimyrna (Lob Injir of Smyrna) is considered by epicures the standard of fig quality, but necessity of caprification, spoilage diseases of the fruit, and the numerous large seeds make it desirable to find other varieties more free from these objectionable features. One of the objects of fig breed-

ing is to develop a variety of common fig which will normally produce one or two crops of fruit by parthenocarpy; if caprifigged, however, these figs with their fertile seeds should more nearly approximate the Calimyrna in quality.

To summarize: The caprifig, the most primitive type of *Ficus carica*, shows parthenocarpic development in some varieties; in the Croisic, an edible caprifig, parthenocarpy is complete in one crop and sometimes in both crops. In Smyrna-type figs parthenocarpy is found to a limited extent only in the first crop of certain varieties. In the White San Pedro group parthenocarpy occurs in the first crop and non-parthenocarpy in the second crop of the same tree in the same season. In common figs there is complete parthenocarpic development in one or two crops of most varieties, but the completeness of fruit setting and maturity is dependent to a considerable extent upon the environmental complex. There is very little data available on the inheritance of parthenocarpy in figs, but the fruiting of several thousand seedlings now being grown should provide such data in the near future.

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## Girdling to Reduce Fruit-Drop in the Hachiya Persimmon

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WHEN the Hachiya persimmon, the principal variety of *Diospyros kaki* grown in California, is planted in solid blocks, or mixed with other pistillate varieties, failure to mature satisfactory crops is characteristic of young and vigorous trees and fruit development is parthenocarpic. If provided with cross-pollination, the fruit is seedy and the trees come into bearing early and bear heavily. At maturity, however, unpollinated trees seem to bear as heavily as pollinated trees; the seedless fruit is, of course, preferable.

The unsatisfactory crops produced by young and vigorous trees are not caused by deficiency in fruit-bud differentiation or failure to set enough fruits; the trees normally blossom well and set many fruits. The failure to mature these fruits is caused by excessive fruit-drop; almost continuous shedding of fruits occurs from the period of fruit-set, in late spring, until a few weeks before the harvest season, in early fall. Starting with a good crop, it is not uncommon for vigorous young trees to end the season without a single fruit.

The causes for this excessive fruit-drop are not known. It does not occur if pollination takes place and the fruit is seedy. To some extent, it appears to be related to weather conditions and soil moisture supply; hot and dry summer weather and soil moisture deficiency are observed to accentuate the shedding. The most obvious condition, however, associated with excessive fruit-drop is vigor of growth. So long as the trees continue to grow vigorously they fail to mature satisfactory crops. Thus, young trees whose growth vigor has been reduced by unfavorable soil conditions, or which have suffered injury to the trunk or root system, are observed to come into bearing earlier than trees whose vigor of growth has been prolonged by favorable soil conditions, or maintained by cultural practices.

It seemed probable, therefore, that girdling might be a practicable means by which to control the growth vigor of young trees and thereby reduce significantly the excessive fruit-drop to which they are subject.

### MATERIALS AND METHODS

The trials were conducted at the Citrus Experiment Station, Riverside, on trees which, at the start of the experiment, were 4 and 5 years old. Their size and vigor were below average, the principal factors responsible for which are believed to be low soil fertility, crown gall infection, and bark injury caused by rabbits during the first two seasons after planting. A high degree of variability in size, vigor and yield existed. When later removed, it was found that, almost without exception, the higher yielding trees had root systems badly affected with the crown gall disease. Fifty-three trees, in two parallel rows 24 feet apart, were available for experimentation.

In the 1933 trial, 22 trees were girdled at nine irregular intervals during the period February 24 to December 16, a narrow strip of bark being removed from the trunk; the remaining 31 trees served as controls for that season. For the 1934 trial, 14 of these trees were girdled at three irregular intervals during the period February 2 to July 18; half of the treatments were applied as simple knife cuts, no bark being removed. This left 17 trees which served as controls in both trials. Individual tree yield records were kept for the 1933, 1934 and 1935 seasons, at the end of which the trees were removed.

### RESULTS AND DISCUSSION

The dates of treatment and individual tree yields for the two trials are given in Tables I and II.

A wide range of variation in yield of both untreated and treated trees will be noted; there is also evident a general tendency toward alternation in bearing habit, 38 of the 53 trees exhibiting this tendency, or approximately 70 per cent. In this connection, it should be emphasized that these yields are much above average for trees of the same age growing under more favorable conditions and exhibiting greater vigor of growth.

TABLE I—YIELD IN POUNDS PER TREE FROM TRIALS IN 1933

Tree Number	Date of Treatment	Row 13 Treated			Row 12 Untreated		
		1933 Crop	1934 Crop	1935 Crop	1933 Crop	1934 Crop	1935 Crop
5	February 24	20	49	36	17	45.8	53
6		67	87.5	77	11	73	52
7	March 23	27	45	8	23	62.5	36
8		75	80	10	20	95	44
9	May 6	73	69	38	41	54.5	71
10		61	90	1	42	39.5	82
11	May 25	83	39	54	6	27	81
12		62	47.5	36	36	53.5	67
13	June 28	103	68.5	34	47	43	81
14		115	46	83	52*	43	53
15	July 27	42	33	74	21	15	55
16		—	—	—	18	14	35
17		67	54	21	42	46	96
18		24	29	78	40*	19	76
19	September 11	3.5	14	15	60*	65	70
20		52	96.5	57	61*	33	83
21		24	35	1	34*	38	35
22	October 10	60	79.8	28	56*	35	93
23		62	124	62	46*	52	85
24	November 11	—	—	—	53*	9	81
25		31	102.5	70	—	—	—
26		—	—	—	41*	47	80
27	December 16	9	57.5	48	50*	12	55
28		59	6.5	48	62*	49	73
29		75	15	75	—	—	—
Untreated							
30		9	19.5	16	37*	12	65
31		39	33.5	48	41*	40	55
32		26*	42	19	16*	37	36
33		35*	37	39	45*	20	54

\*Controls also for 1934 trial.



The differences in response of the treated and untreated trees in the two trials are summarized in Tables III and IV.

TABLE II—YIELD IN POUNDS PER TREE FROM TRIALS IN 1934

Row and Tree Number	1933 Crop Preceding Treatment	Date of Treatment	Treated		Untreated			
			1934 Crop Season of Treatment	1935 Crop Season After Treatment	Row and Tree Number	1933 Crop	1934 Crop	1935 Crop
13(30)	9	February 2	19.5	16	12(32)	26	42	19
13(31)	39		33.5	48	13(33)	35	37	39
12(5)	17	April 28	45.8	53	12(14)	52	43	53
12(6)	11		73	52	12(18)	40	19	76
12(7)	23		82.5	37	12(19)	60	65	70
12(8)	20		95	44	12(20)	61	33	83
12(9)	41	June 9	54.5	71	12(21)	34	38	35
12(10)	42		39.5	82	12(22)	56	35	93
12(11)	6		27	81	12(23)	46	52	85
12(12)	36		53.5	67	12(24)	53	9	81
12(13)	47	July 18	43	81	12(26)	41	47	80
12(15)	21		15	55	12(27)	50	12	55
12(16)	18		14	35	12(28)	62	49	73
12(17)	42		46	96	12(30)	37	12	65
—	—	—	—	—	12(31)	41	40	55
—	—	—	—	—	12(32)	16	37	36
—	—	—	—	—	12(33)	48	90	84

TABLE III—SUMMARY OF TRIALS IN 1933

Treatment	Number of Trees	Average Yield per Tree (Pounds)			
		1933 Crop	1934 Crop	1935 Crop	3-Year Average
<i>Untreated</i>					
a. Paired with treated trees . . . . .	18	36.4	—	—	—
b. All possible controls . . . . .	31	36.3	—	—	—
1. Treated in 1934 . . . . .	14	26.6	—	—	—
2. Permanent controls . . . . .	17	44.4	34.7	61.8	47.0
<i>Treated</i>					
a. For the period Feb. 24 to Oct. 10 . . . . .	18	56.6	60.3	39.6	52.2
b. For the period Feb. 24 to July 27 . . . . .	13	63.0	56.7	42.3	54.0
c. For the period March 23 to July 27 . . . . .	11	66.5	54.3	39.7	53.5
d. For the period March 23 to June 28 . . . . .	8	74.9	60.6	33.0	56.2
e. For the period May 6 to June 28 . . . . .	6	82.8	60.0	41.0	61.3
f. For the period June 28 to Oct. 10 . . . . .	10	55.3	58.0	45.3	52.9

TABLE IV—SUMMARY OF TRIALS IN 1934

Treatment	Number of Trees	Average Yield per Tree (Pounds)		
		1934 Crop	1935 Crop	2-Year Average
<i>Untreated</i>				
a. Controls . . . . .	17	34.7	61.8	48.3
<i>Treated</i>				
a. For the period February 2 to July 18 . . . . .	14	44.4	58.4	51.4
b. For the period April 28 to July 18 . . . . .	12	47.4	62.8	55.1
c. For the period April 28 to June 9 . . . . .	8	56.4	60.9	58.7
d. For the period June 9 to July 18 . . . . .	8	36.6	71.0	53.8

*Effect of Girdling on Crop of the Current Season:*—In both trials, it will be observed that the yields of the treated trees were higher than those of the untreated or control trees for the current season of treatment, the difference being greatest in the 1933 trial. It will be noted, however, that the two groups of untreated trees into which the 31 possible controls were divided for the 1934 trial were higher and lower in yield respectively than the control group as a whole or the 18 untreated trees paired with the treated trees. It seems a reasonable assumption, therefore, that the treated trees in the 1934 trial were a group of lower than average yield whereas the 17 controls comprised a group of higher than average yield; this may account for the smaller difference between the treated and untreated trees in this trial. It is concluded that girdling materially reduced fruit-drop during the current season of treatment and thereby increased yield.

*Effect of Girdling on Crop of the Succeeding Season:*—Table III shows a substantially higher average yield in 1934 for the trees treated in 1933 than for the controls. In Table IV, however, it will be seen that the trees treated in 1934 averaged slightly lower in yield in 1935 than the controls. It should be emphasized, in this connection, that the 17 control trees in this trial were originally higher in average yield than the 14 treated trees. Moreover, it will be observed, in Table II, that 10 of the 17 control trees alternated in yield, with the on-crop phase coming in 1935, whereas only five of the 14 treated trees followed this behavior. It is therefore concluded that girdling not only increases yield in the crop of the current season but also for the season following the treatment.

At least part, and possibly all, of the increase in crop the season following treatment is believed to have been the result of increased fruit-bud differentiation. In both trials the treated trees produced a heavier bloom the season following treatment than did the untreated trees; this was especially marked in the 1933 trial.

*Effect of Two Increased Crops on the Succeeding Crop:*—That the increase of crop for two seasons, caused by girdling, is attended by marked reduction in yield in the succeeding crop is indicated in Table III. The control trees, it will be noted, increased materially in yield in 1935, whereas the treated trees decreased. This behavior, which appears to be contrary to the normal trend, is considered to comprise evidence confirmatory to the conclusion above noted relative to the effect of girdling on the amount of crop the season following treatment.

*Effect of Time of Girdling:*—Notes taken at the periods of treatment show that the bark separated readily from the cambium during the period March to July, inclusive, but that at other times it separated with difficulty and had to be cut away. Detailed observations on the 1933 trial, made April 28, 1934, showed the girdles to be completely healed over on the trees treated in March, April and May of 1933 and nearly healed over in the February and June treatments; the healing in other treatments ranged from 10 to 50 per cent.

In both trials, where girdling was done while the trees were in leaf, slight wilting was observed for several weeks after treatment; recovery seemed to occur more rapidly where a simple knife cut was employed

than where a strip of bark was removed. Under conditions of water stress, either high temperature or soil moisture deficiency, it was observed that the treated trees wilted slightly, in contrast with the controls.

Foliage size and color the season after treatment appeared not to be affected by girdling in November, December, February, late May and June; the leaves of the trees in the March, early May and October treatments were normal in size but noticeably pale in color. The remaining treatments caused the production of abnormally small, pale-colored leaves. In the late summer of 1934 the trees treated in July, September and October of 1933 were obviously in very poor condition and those treated in the latter two months were badly wilted. In the spring of 1935 these trees showed considerable die-back and were much retarded in leafing-out; it was evident that they had been badly injured.

From the point of view of tree injury, therefore, the period approximately May 15 to July 15 is indicated as that safest for girdling treatment.

Tables III and IV indicate that, in both trials, this is the period during which girdling produces the maximum effect in reduction of fruit-drop, as reflected in yield. In the 1933 trial, however, it will be noted that earlier treatment, April and May, was associated with maximum yield the season following treatment, whereas the data for the 1934 trial show no consistent trend or relations. This may account for the fact, already noted, that the trees in the 1933 trial blossomed much more heavily the season following treatment than did the trees in the 1934 trial.

Summed up, the evidence seems to point to the period approximately May 15 to June 15 as that safest and most effective for treatment.

*Effects of Increased Crop on Size and Quality of Fruit:*—As would be expected, the larger crops which resulted from girdling were associated with smaller size of fruit; in all cases, however, the fruit attained commercial size. Likewise, the larger crops resulted in a lower per cent of high quality fruit, more of the fruit being exposed and thereby affected by sunburn. The crops on the injured trees were the worst affected. Breakage, from wind action, was also worse on the treated trees, though not of much consequence.

#### CONCLUSIONS

Two girdling trials on young, unpollinated Hachiya persimmon trees, where the crops are the result of parthenocarpic fruit development, provided data from which are drawn the following conclusions: (a) Girdling materially reduced fruit-drop during the current season of treatment and thereby increased yield. (b) Yield was also increased in the crop of the season following the treatment; part of the increase was apparently the result of greater fruit-bud differentiation. (c) The effect of two increased crops, caused by girdling, was to markedly reduce yield the following season. (d) The period approximately May 15 to June 15 was the safest and most effective for treatment. (e) The increased yield which resulted from girdling was associated with smaller size of fruit and lower commercial quality, caused principally by sunburn.

## Relation of Seeds to Pre-Harvest McIntosh Drop<sup>1</sup>

By LAWRENCE SOUTHWICK, *Massachusetts Agricultural Experiment Station, Amherst, Mass.*

A SERIOUS problem in the production of McIntosh apples is excessive dropping of the fruits just prior to picking maturity. This difficulty often forces the orchardist either to harvest the crop prematurely, before optimum size, color, and quality are obtained, or to await optimum fruit development with the resulting increased percentage of drops. The premature fruit abscission tendency seems to be a varietal characteristic and is found also in varieties other than McIntosh such as Wealthy, Fameuse, and Gravenstein. With McIntosh, however, the problem is particularly acute in many sections because of the trend toward extensive commercial plantings together with a practically universal insistence upon high color and quality development.

The actual abscission process as recently described by MacDaniels (11) and McCown (12) must be initiated and stimulated by one or several underlying causes. The importance of living embryos and seed development in connection with the set and early growth of fruits has been observed, (1, 2, 4, 5, 6, 13, 14, 15). In general, the factors influencing the abscission of blossoms and young fruits have not been considered identical with those causing pre-harvest fruit drop (10). The evidence regarding the significance of seeds in influencing this drop is fragmentary.

In 1936, a study was undertaken to determine the cause of the highly variable dropping behavior of McIntosh apples just preceding and during the usual harvest period. In late August, all the apples on a few representative limbs of four trees were numbered with India ink and natural abscission was allowed to go to completion. From the first week in September to the middle of October the "drops" were gathered at least once a day, and put into storage for subsequent analysis. Among other data, seed counts were taken. The study was continued in 1937 when all the apples on three trees were numbered. Only one tree, J-10, was utilized in both 1936 and 1937. A follow-up survey in 1938 was disrupted by the September hurricane. It should be pointed out that it was not possible to segregate, from the natural drops, the apples accidentally jarred from their spurs by other falling apples. Since the effect of this variable factor of collision was not taken into consideration, the reported associations may well be conservative. Table I gives the drop data and computations.

In the first place, it is seen how variable are the mean drop dates, which show in each case when 50 per cent of the total tree crop had abscised. B-6 in 1936 and G-18 and F-25 in 1937 illustrate cases of possible severe pre-harvest fruit drop on the commercial fruit farm. There seems to be no correlation, among different trees, between average number of seeds and mean dates of drop. The mean seed

<sup>1</sup>Contribution No. 332 of the Massachusetts Agricultural Experiment Station.

TABLE I—McINTOSH DROP DATA FOR 1936 AND 1937 FROM INDIVIDUAL TREES IN THREE BLOCKS

Tree	Mean Date of Drop	Number of Drops Studied	Mean Number of Seeds per Fruit	Coefficient of Correlation—Seed Number and Date of Drop	Per Cent Apples With One or More Empty Locules
1936					
B-6	September 16	933	8.0	$+ .348 \pm .019$	21
B-7	September 19	289	7.2	$+ .542 \pm .029$	36
J-10	September 19	347	6.2	$+ .318 \pm .033$	39
J-12	September 25	369	7.9	$+ .279 \pm .032$	19
1937					
G-18	September 13	1937	9.3	$+ .302 \pm .018$	11
F-25	September 16	1433	9.5	$+ .264 \pm .016$	8
J-10	September 25	2630	6.2	$+ .270 \pm .012$	46

numbers seem to have been dependent upon the extent of effective pollination in each case. Thus tree J-10 is in a solid McIntosh block, while G-18 and F-25 are interplanted with Wealthy fillers. Trees of other varieties nearest to J-10 which might afford a chance for cross-pollination consist of several sorts, mostly early, in a variety block to the east of tree J-10. The variable ability of different pollens to cause seed to develop in McIntosh fruit has been observed (2, 3, 7).

With individual trees, the positive correlation coefficients between seed number and date of drop are highly significant. However, the rather low actual coefficient values indicate only moderate association even though with B-7 the coefficient value .542 indicates a possible effect of seeds on time of drop of approximately 30 per cent. Tree J-10 was used both in 1936 and 1937 and it should be noted that the mean seed numbers for both years were the same. The difference between the coefficients of correlation for the 2 years is not statistically significant (9) indicating a constant relationship between time of drop and fruit seed number for the 2 years. It is seen also that the seed-drop date association is manifest regardless of the actual seed number, the means varying from 6.2 to 9.5. A normal McIntosh ovary may contain 20 ovules (8) which may, of course, develop into as many seeds provided perfect fertilization is followed by uninterrupted growth. In this connection it is interesting to note that the number of mature seeds per fruit actually did vary from 0 to 20, with 21 seeds found in a single case. The percentage of empty locules varied roughly with seed numbers, but the majority of fruits were normal in shape regardless of time of drop. Proportionately few of the apples were seriously malformed despite the fact that many contained no developed seeds. It seems that early season abnormalities of shape due to empty locules are quite likely to be outgrown if the affected fruits are able to remain on the tree.

#### CONCLUSION

Studies reported in this paper reveal a moderate but statistically significant correlation between seed number and time of pre-harvest drop of the McIntosh apple. Seed content varied widely among different trees, probably as a result of variability in the effectiveness of

pollination, but this did not seem to alter appreciably its association with the date of drop.

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# A Preliminary Report on the Productiveness of Secondary and Lateral Peach Shoots<sup>1</sup>

By T. E. ASHLEY,<sup>2</sup> *Mississippi State College,  
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IN the opinion of some investigators, secondary shoots of the peach, that is, shoots arising from lateral buds of current season's growth, are as productive as lateral shoots or those arising from wood 1 year old or older. Since there are no data concerning the productiveness of secondary shoots, their value is not known. To determine their value this study was undertaken.

Uniform 5-year-old trees of the Hiley peach, of moderate vigor, growing on a clay loam soil with sandy clay subsoil, were used. The soil management practice has been clean culture with a winter cover crop of vetch plus applications of nitrogen-carrying fertilizers.

TABLE I—DATA SHOWING FRUIT BUDS PER SHOOT, VEGETATIVE BUDS PER SHOOT, TOTAL BUDS PER SHOOT, PER CENT FRUIT BUDS OF TOTAL BUDS, FRUITS AFTER JUNE DROP, AND PER CENT FRUIT SET OF LATERAL AND SECONDARY PEACH SHOOTS

Kind of Shoot	Number of Shoots	Average Length of Shoot	Fruit Buds Per Shoot	Vegetative Buds Per Shoot	Total Buds Per Shoot	Fruit Buds (Per Cent of Total Buds)	Fruits After June Drop Per Shoot	Fruit Set (Per Cent)
<i>0 to 3 Inches</i>								
Lateral	25	1.99	4.40	1.64	6.04	72.85	.36	8.23
Secondary	25	1.98	1.53	3.26	4.79	31.94	.13	3.88
<i>3 to 6 Inches</i>								
Lateral	25	4.59	6.00	4.80	10.80	55.55	1.36	25.76
Secondary	25	4.55	2.64	4.84	7.48	35.29	.12	4.13
<i>6 to 12 Inches</i>								
Lateral	25	9.40	7.68	8.64	16.32	47.06	1.52	21.66
Secondary	25	8.87	4.72	6.96	11.68	40.41	1.08	22.79
<i>12 to 18 Inches</i>								
Lateral	25	14.40	10.96	11.20	22.16	49.45	2.00	19.30
Secondary	25	15.28	3.52	13.88	17.40	20.23	.44	8.86

Shoots were measured and divided into four classes as follows: (a) 3 inches or less in length, (b) 3 to 6 inches, (c) 6 to 12 inches, and (d) 12 to 18 inches in length. The classes of each type consisted of 25 shoots. In each case all shoots in the same class were on the same tree, that is, both the secondary and lateral shoots of the 3 to 6 inch class were on the same tree.

Counts of both vegetative and fruit buds were made February 13, about 1 week before full bloom. Fruit counts were made April 5 soon after the June drop. Because of unfavorable weather conditions during

<sup>1</sup>Contribution from the Horticulture Department, Mississippi Agricultural Experiment Station, State College, Mississippi. Published with the approval of the Acting Director, Mississippi Agricultural Experiment Station. Paper No. 7, New Series.

<sup>2</sup>The data contained in this paper were collected by J. T. Shows, Student Assistant, Department of Horticulture.

the pollination period very few fruits set on either the secondary or lateral shoots.

It is shown in Table I that the average length of the shoots in each of the individual classes was approximately the same. The data also show that in each instance the number of fruit buds per shoot, total buds per shoot, and average number of fruits per shoot was greater in the lateral shoots; and that in all cases except the 6- to 12-inch class the per cent of fruit set and the total fruits matured was greater in the lateral shoots than in the secondary shoots.

Based upon the number of fruit buds formed, the results of this preliminary investigation indicate that the lateral shoots of Hiley are potentially much more productive than are secondary shoots.



# The Effect of a Plant Growth Substance on Crotch Angles in Young Apple Trees<sup>1</sup>

By LEIF VERNER, *University of Idaho, Moscow, Idaho*

IN training and pruning fruit trees it is a matter of common observation that a scaffold branch forming a narrow angle at the point of union with the tree trunk is structurally weak. MacDaniels (5) has shown that this is due to inclusion of bark in the narrow crotch between the branch and the trunk, and to failure of contiguous tissues of the trunk and branch to unite and grow together. In a wide angled branch a woody structure forms in the crotch, uniting crotch tissues of the branch with adjacent tissues of the trunk. Such branches have great strength and are capable of supporting heavy crops of fruit without breaking down, while the narrow angled type of branch is in danger of breaking at the crotch under the weight of even a moderate crop of fruit or as a result of action of the elements. In many orchards a large percentage of scaffold branches are of the acute angled type, and such orchards not infrequently suffer serious, permanent damage as a result of breakdown of the trees.

A further objectionable feature in the narrow angled scaffold branch has recently been emphasized by the work of Horsfall and Vinson (3) who have shown that the tissues of narrow angled crotches are more susceptible to winter injury than are the corresponding tissues in crotches formed by wide angled branches.

Crotch angles in apple trees vary greatly from branch to branch and from tree to tree. Some varieties, as Delicious and Stayman Winesap, are especially prone to develop narrow angles while other varieties, such as Jonathan and York Imperial, normally form crotches that are very wide. There has been but little study of the fundamental causes of such differences.

Blake (1) concluded that narrow crotch angles in apple trees are the result of rapid branch growth, as he found these two characteristics associated. Horsfall (2) suggests that the ratio of trunk diameter to the diameter of a lateral shoot has a bearing on the magnitude of the angle that is formed; a high ratio, such as found in the lower portions of the tree, inducing wide angles. Horsfall and Vinson (4) consider that the mechanical action of a rapidly enlarging trunk may force a more or less vertically inclined lateral shoot towards a horizontal position, the tissues of the shoot being, at such a time, plastic and unable successfully to resist this growth pressure.

A study of this problem was carried on at the University of Idaho in 1937 and 1938. The present paper, reporting the results of certain phases of this study, is not presented as a contribution to our knowledge of the fundamental principles of hormone action in plants. It is presented, rather, as a new application of these principles to a specific problem. No attempt is made at this time to review the extensive

<sup>1</sup>Published with the approval of the Director of the Idaho Agricultural Experiment Station as Research Paper No. 179.

literature on phytohormones that might have a bearing on the observations recorded.

### EXPERIMENTS IN 1937

Approximately 200 apple trees of the varieties Delicious, Yellow Transparent and Jonathan were planted as 1-year-old nursery whips in the spring of 1937. These trees were subjected to different treatments that might be expected to have some influence on the crotch angles of branches formed in the current growing season. Such treatments included shading, girdling, differential fertilization and irrigation and different systems of training. At irregular intervals during the growing season measurements of all crotch angles and branch lengths were taken on several representative trees in each treatment. The present paper deals only with experiments on the Delicious variety. In keeping with a conventional practice in starting nursery trees in the orchard, these were all cut back to a height of approximately 30 inches before growth began and before any special treatments were given.

At a time when the most advanced shoots had attained a length of about 10 centimeters and the most delayed buds were just beginning to grow, several of the young trees were bent over and their tips fastened to stakes driven into the ground. This treatment was designed to change the direction of branch growth in relation to the trunk in order to determine if the branch angles at any of the stages of development represented had become permanently fixed, or if they still remained subject to alteration by external influences, such as a change in the incidence of phototropic or geotropic stimuli.

Girdling was effected by means of two incisions of a knife blade, about  $\frac{1}{8}$  inch apart, extending around the stem and completely severing the phloem. In some cases the intervening strip of bark was removed while in others it was undisturbed. Individual buds were treated by removing, from immediately above them, a narrow, horizontal strip of phloem tissue just long enough to embrace the full width of the bud.

### RESULTS AND DISCUSSION OF 1937 EXPERIMENTS

In all trees on which measurements were taken there was a slight but consistent increase in crotch angles from the time the shoots first attained a length sufficient to make measurements possible (about 5 to 10 millimeters) until the lower portion of the branch began to assume a woody nature. This increase in branch angles during the early period of growth ranged from 1 to 15 degrees. Apparently, when there was no further increase in its magnitude the angle had become more or less permanently fixed and was not thereafter likely to be altered. Thus, in the trees that were bent over and staked in an arched position the branch tips soon turned upward, but there was virtually no change in the crotch angles of most of these branches, the entire upward curvature having taken place in that portion of the stem in which internodes still were elongating (Fig. 1). Only in a few very short shoots in which the basal tissues still were plastic at the time

of bending was there any abnormal modification of the initial angle following this treatment.

In all trees except those treated by injuring the phloem (as in girdling) there was a progressive increase in branch angles from the apex towards the base of the tree. The uppermost two or three branches invariably formed narrow angles, and the lowest branches, as a group, always had a wider average angle than any comparable group of branches higher on the trunk. When the phloem had been severed, however, this normal relationship between the angle of a branch and its position on the trunk was always upset. Removal of a narrow strip of phloem immediately above a bud, as described, if the injury occurred before or shortly after the bud began to grow, invariably resulted in development from that bud of a branch with a much narrower angle than those of branches immediately above and below the treated one. On trees in which each internode was girdled while the buds still were dormant all the branches that developed had narrow angles, and the same was true of trees in which every third internode was girdled (Fig. 2A).

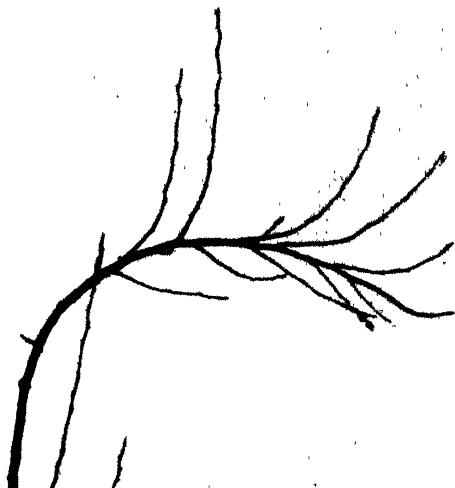


FIG. 1. Delicious tree bent over and fastened in an arched position when lateral branches were partly grown. Except in very short shoots the crotch angles were unaltered by this treatment, indicating early fixation of these angles.

After growth was somewhat advanced, injury to the phloem had a quite different effect. Thus, when a narrow band of this tissue was removed from the trunk just above a shoot between 2 and 10 centimeters in length the crotch angle was unaffected, but usually this treatment was followed by an upward curvature of the shoot at a point just below where the tip had been when the phloem was cut. This curvature, which changed the direction of growth by 10 to 25 degrees, took place, in other words, in a portion of the shoot that still was elongating. The fact that severance of the phloem did not noticeably alter the angles of shoots that had attained a length of 2 centimeters or more is further evidence of early, permanent fixation of crotch angles in these trees.

There is considerable evidence in the observations reported above that the angle of departure of a branch from the trunk of a young apple tree is determined largely by the action of a plant growth regulator of some sort. This might be formed in any of the growing points of the young tree and transported downward through the phloem to exert an

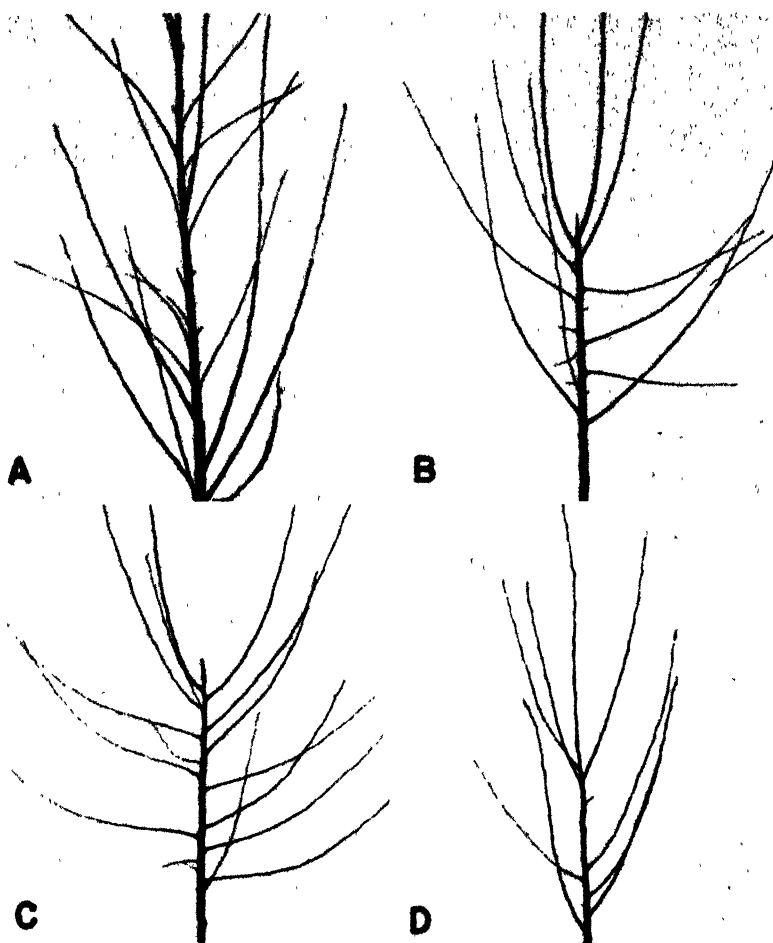


FIG. 2. Delicious apple trees showing the first years branch growth from whips variously treated. A, Narrow branch angles formed throughout the entire tree following girdling of every third internode in the late dormant period. B, Abnormally wide angles developed by two branches following treatment of the basal internodes with indole-butyric acid in lanolin paste. C, Broad angles formed throughout an entire tree following application of an auxin paste in a rubber tube fastened over the terminal end after heading back to 30 inches. D, Untreated except by heading back to 30 inches when planted.

influence on the direction of growth of shoots below the point from which the growth substance emanates.

This substance apparently acts on a newly developing lateral shoot in such a way as to alter the ratio of growth of its upper and lower surfaces, the upper surface under the influence of the hormone making relatively more growth than the lower surface and thereby increasing the angle between the shoot and the trunk. Girdling or similar injury

to the phloem should effectively block the downward movement of this growth substance and permit branches immediately below the girdle to assume narrower angles.

Further evidence of such hormone action is afforded by the observation that in all the trees studied the crotch angles were found to be progressively wider as measurements were taken from the top to the base of the tree. The uppermost two or three branches, which invariably have narrow angles, are so arranged around the central stem that none of them lies directly below another; therefore, unless there is considerable lateral movement of the hormone, which is unlikely, these branches would hardly be expected to exhibit the correlation phenomenon here considered. The lower branches, on the other hand, should feel the cumulative effect of the hormone formed by many growing points above and they would, in consequence of this, be expected to form relatively broad angles.

#### EXPERIMENTS IN 1938

Experiments conducted in 1938 included the use of a synthetic plant growth substance, indole-butyric acid, which was employed in several different ways. One-year-old, unbranched Delicious apple trees from 4 feet to 6 feet high were used in most of this work, and all of the trees treated with the auxin had been cut back to a height of about 30 inches before growth began and prior to any other treatment.

Indole-butyric acid mixed with lanolin paste in concentrations of 5 to 25 milligrams per 100 grams of lanolin was applied to the upper surfaces of the basal portions of shoots from 1 to 2 centimeters in length, and to basal,<sup>2</sup> median, and terminal internodes of shoots from 5 to 20 centimeters long. A dense pubescence caused some difficulty in securing intimate contact of the auxin paste with the outer tissues of the shoot, but this difficulty was overcome by using a small, rather stiff brush in making the applications.

By fastening one end of a 2-inch length of rubber tubing over the cut, terminal portion of a dormant whip and injecting a small amount of the auxin paste into this tube, provision was made for a continuous, small supply of the growth substance to move by diffusion into the tree from a point above the uppermost bud. This type of treatment was continued for 5 weeks or longer. In all cases in which auxin paste was used control trees were treated in the same manner with lanolin alone.

#### RESULTS AND DISCUSSION OF 1938 EXPERIMENTS

Direct applications of indole-butyric acid paste to young lateral shoots gave various results depending upon the time and position of the application. Change in direction of growth of the young shoot occurred only when the paste had been applied unilaterally on an internode that still was elongating. When so used a negative curvature resulted, as though the auxin had increased the rate of growth of the tissues with which it had come in direct contact. Thus, when the paste was applied to the upper surface of the still elongating basal internode

<sup>2</sup>The term "basal internode" is used here to denote the first elongated internode of the shoot.

of a very young, more or less upright-growing shoot, the direction of growth soon inclined more towards the horizontal and the angle formed between the upper face of the shoot and the trunk was thereby increased (Fig. 2B). As a rule the angle so formed did not exceed 90 degrees; but if the paste was applied to two or three adjoining internodes, none of which had completed its normal elongation, the resulting curvature sometimes was sufficient to turn the shoot downward to the point where the tip was directed almost vertically towards the earth.

Applications of the auxin paste to the second or third internodes, rather than the basal one, usually caused the direction of growth of the shoot to incline towards a horizontal position but did not alter the angle already established between the trunk and the first internode. It is evident, therefore, that to effect a change in the crotch angle of a shoot by means of a direct application of this auxin it is necessary that the treatment be applied to the basal internode, and at a time when this internode still is increasing in length.

When the growth substance in lanolin was applied to a dormant bud or came in contact with the tender, growing tip of a very young shoot (.5 millimeter or less in length) growth activity seemed arrested and death sometimes ensued within a few weeks. Thus, the interval of time within which the ultimate crotch angle of a branch may be influenced by direct application of this substance is very limited, beginning when the basal internode is sufficiently developed that it can be treated independently without danger of accidental contact of the delicate growing point with the paste, and ending when the basal internode has ceased elongating. This may represent a period of from a few days to a week, depending upon the current rate of growth of the shoots.

The results of these preliminary trials with direct application of an auxin paste to individual shoots do not indicate a clear preference for any particular concentration within the range studied. Its use in various concentrations was followed by the same types of response. The degree of response varied considerably with all concentrations, probably because of slight differences in stage of development and other characteristics of the shoots at the time of treatment. This made quantitative evaluation of different concentrations of the growth substance impossible. In general, however, there seemed to be a positive correlation between concentration of the indole-butyric acid and degree of the epinastic effect on the shoots to which it was applied.

A continuous, small supply of indole-butyric acid slowly diffusing into the apex of the tree, as when a lanolin paste of this substance was injected into a piece of rubber tubing fastened over the cut end of a whip, resulted in development of wide crotch angles throughout the entire tree. The uppermost two or three branches, which ordinarily develop the most acute angles, were most obviously affected. Fig. 2C shows a Delicious tree treated in this manner, and in Fig. 2D is shown a representative, untreated tree of the same variety. The terminal three branches of the treated tree had an average crotch angle of 59 degrees; those of the untreated tree, 35 degrees. The average of all branch angles on the treated tree was 65 degrees, and the average for all branches on the untreated tree was 48 degrees.

This terminal application of the paste was much the simplest and most effective method used. In no case did the use of lanolin paste alone have any noticeable effect on branch angles in these trees.

Although these investigations have not yet progressed to a point where practical applications can be recommended, the possible bearing of a hormone action on certain problems in training apple trees might be pointed out. According to Blake (1), when nursery whips are trained by debudding, a practice in which four or five dormant buds rather widely spaced on the trunk are selected to form permanent branches and all other buds are removed, the branches that arise from the selected buds are inclined to form narrow crotches. Blake attributes this to unusually rapid growth of the small number of shoots allowed to develop. In the light of observations here reported it seems more likely that this effect is attributable to a subnormal supply of hormone due to a greatly reduced number of growing points. In choosing the buds to be retained in training a tree by this method, a special effort is made to avoid selection of buds directly above one another. If we assume that movement of the hormone is largely confined to a longitudinal direction, as is probably the case, these selected buds should be relatively free of the hormone action.

Wider crotch angles should be obtained if the selection of permanent scaffold branches were deferred until most of the shoots have attained a growth of at least an inch. This should give time for the hormone action to exert its influence on the branch angles; and most of these, by that time, should be permanently fixed. For the same reason, trees trained by the usual method of cutting them back at planting time to a height of 30 inches, more or less, probably would develop somewhat wider crotch angles if this operation were deferred until a moderate amount of shoot growth has taken place.

#### SUMMARY

Narrow crotch angles in the framework of fruit trees are structurally weak and may lead to serious breakdown of trees in which they occur. A study of factors that influence the magnitude of crotch angles in young Delicious apple trees planted as 1-year-old nursery whips showed that injury to the phloem immediately above a dormant bud, as by girdling, invariably resulted in development of an abnormally narrow angled branch from that bud. This, together with certain other observations, lead to the conclusion that wide crotch angles result from the action of a plant hormone formed in the growing points of the young tree and passed downward through the phloem to buds and developing shoots below, where its action inclines the direction of growth of the shoot towards a horizontal position.

When indole-butyric acid in lanolin paste was applied to the upper surface of the basal internode of a young shoot when this internode still was elongating a marked increase in magnitude of the angle formed by the trunk and the shoot soon was observed. After elongation of the basal portion of the shoot had ceased and the tissues of this region had assumed a woody nature, the crotch angle was permanently fixed and neither girdling nor auxin treatment would alter it.

By a simple technique, which is described, indole-butyric acid was permitted to diffuse slowly and over a long period into the cut, terminal portions of whips that had been headed back to about 30 inches while still dormant. Under this treatment abnormally wide crotch angles were developed throughout the entire tree.

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# Respiration and Emanation of Volatiles from Bartlett Pears as Influenced by Ripening and Storage

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**B**ARTLETT pears, after prolonged ripening or storage at low temperatures, are subject to certain physiological disorders such as scald and core-breakdown (4, 5). That a correlation exists between the incidence of such disorders and the accumulation of certain volatiles as ethyl alcohol and acetaldehyde, within the tissues of pear fruits, has been shown by the work of Harley (4), Gerhardt and Ezell (2), and Kidd, *et al.* (6).

It is generally accepted that respiratory intensity is a direct physiological index of such processes as maturation, ripening and senescence of fruits. Respiration is also directly correlated with plant growth in general, as Palladin (10), states that the form of the grand curve of respiration "is practically identical with the grand curve of growth." In the present preliminary studies, the rate of respiration, as measured by the output of carbon dioxide, has been used as a guide to the metabolic activity of mature Bartlett pears when subjected to various handling practices after harvest. A study has been made of the inter-relationship of the respiratory activity, the emanation of total volatiles, and the accumulation of acetaldehyde within the tissues of Bartlett pears.

## MATERIAL AND METHODS

Bartlett pears, harvested at 16.6 pounds pressure (U. S. D. A. pressure tester) on August 25, 1937, were placed immediately in a ripening room at a temperature of 65 degrees F and a relative humidity of approximately 80 per cent. Observations were made on this fruit over a period of 26 days, at the end of which time it was completely scalded and broken down at the core. Comparable fruit at harvest was stored immediately at 32 degrees for 58 days and then held at 65 degrees for an additional 14 days.

Respiratory measurements were made on tared and aerated fruits by absorbing the respired carbon dioxide in Truog towers containing barium hydroxide. Acetaldehyde was determined, after steam distillation of the tissues, by the Ripper method as described by Fidler (1). The emanation of total volatiles was measured by trapping these substances in concentrated sulphuric acid (specific gravity 1.84), oxidation with an excess of standard ceric sulphate, and subsequent evaluation by iodometric titration with sodium thiosulphate according to the method of Gerhardt and Ezell (3).

## RESULTS

Determinations were made of the respiratory activity and the emanation of volatiles from Bartlett pears held at 65 degrees F immedi-

ately following harvest. Observations as to color, rate of ripening, and presence of scald and core breakdown were also recorded. These results are presented in Fig. 1.

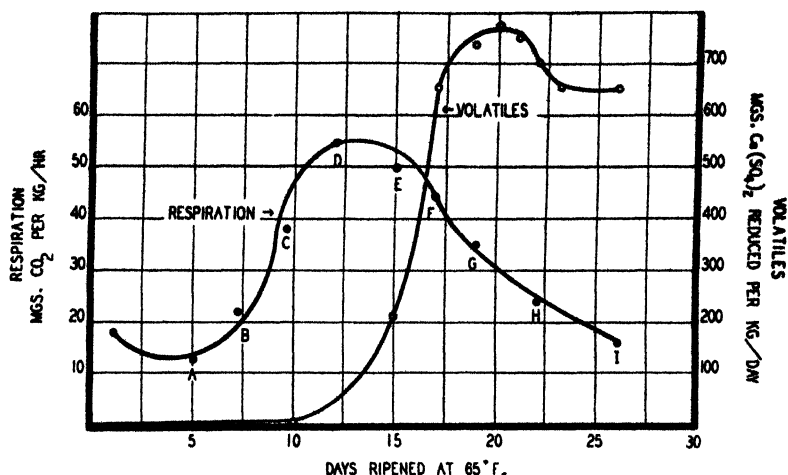


FIG. 1. Respiration and emanation of volatiles from Bartlett pears at harvest. A, harvest green; B, slight yellow; C, full yellow, some fruits ripe; D, full ripe, excellent dessert quality; E, slightly overripe; F, overripe, no scald or core-breakdown; G, some surface scald; H, severe scald and core-breakdown; I, completely scalded and broken down.

During the first 5 days at 65 degrees F the fruit remained harvest-green in color and the respiration rate decreased from 17.8 to 12.7 milligrams CO<sub>2</sub> per kilogram-hour. Numerous studies involving the ripening of Bartlett pears from various producing districts led Magness *et al.* (8) to conclude that there was a considerable interval after picking before softening began. At 65 degrees F this interval was at least 6 days. Respiratory activity evidently is closely correlated with the rate of softening of Bartlett pears, since as shown in Fig. 1, a similar period elapsed before the respiration rate began to accelerate very markedly. The curve of the respiration rate in this instance is similar to those reported by Magness and Ballard (7) wherein Bartlett pear fruits from different producing areas were harvested during several seasons. That a rapid change occurred in the metabolic activity of this fruit between the fifth and tenth days is indicated by the slope of the respiratory curve, and by the color and condition of the fruit. During the first 10 days of ripening, however, the gross emanation of volatiles was practically nil. The respiratory intensity reached a climacteric in 12 days. The fruit was full ripe and of excellent dessert quality at this time. At this critical stage in the metabolism of the fruit, volatile emanation began to increase at a tremendous rate, and, as the curve in Fig. 1 indicates, continued to rise for an additional period of 8 days.

Respiratory activity continued to decrease with each progressive stage of over-ripeness or senescence of the fruit, until after 26 days it had declined over 70 per cent. At this time the fruit was completely

scalded and broken down at the core. Volatiles, on the other hand, reached their highest level 8 days after the respiratory climacteric and just prior to complete collapse of the fruit tissues. Both of these curves are S-shaped in character and typify true autocatalytic reactions (9). Reactions of this type are capable of self-catalysis and proceed slowly at first, rapidly increase to a maximum, and then decline in rate.

Attention was also directed toward following the respiratory activity, emanation of volatiles, and the accumulation of acetaldehyde in the tissue of Bartlett pears during storage at 32 degrees F, and during ripening at 65 degrees after prolonged storage at the lower temperature. Data for these observations are presented in Table I.

TABLE I—RESPIRATION, VOLATILE EMANATION, AND ACETALDEHYDE CONCENTRATION OF BARTLETT PEARS AS INFLUENCED BY DURATION OF STORAGE AT 32 DEGREES F AND BY RIPENING AT 65 DEGREES F

Time (Days)	Respiration (Mg CO <sub>2</sub> per Kg/Hr)	Volatiles (Mg C <sub>6</sub> (SO <sub>2</sub> ) <sub>2</sub> Oxidized per Kg/Day)	Acetaldehyde in Tissue (Mg per 100 Grams of Fresh Tissue)	Color and Condition
<i>Stored at 32 Degrees F</i>				
5	4.0	0.00	0.27	
15	4.0	0.00	—	
58	6.9	8.60	0.59	
68	6.9	8.39	0.67	
97	5.3	47.86	5.07*	
<i>Ripened at 65 Degrees After 58 Days at 32 Degrees F</i>				
1	46.28	—	1.04	Some yellow color.
3	68.95	106.6	1.23	Full yellow, some softening.
5	60.90	370.5	5.29	Soft, off-flavor.
7	47.40	742.0	8.04	Some surface scald and core breakdown.
10	42.80	896.1	11.10	Severe scald and core breakdown.
14	30.10	405.2	4.18	Tissue broken down and discolored.

\*Showing surface scald in storage at 32 degrees F.

The respiratory activity at 32 degrees F attained a climacteric between the 58th and 68th days of storage. A relationship between the respiratory intensity and the rate of softening of Bartlett pears is again reflected in those lots of fruit held continuously at 32 degrees F. Under these conditions the fruit did not soften appreciably and the respiration rate accelerated but slightly. No measurable amount of volatiles could be detected in the aspiration stream from this fruit during the first 15 days of storage. As in fruit ripened at 65 degrees (Fig. 1), the volatiles began to increase rapidly after the occurrence of the respiratory climacteric and increased 6-fold during the next 30 days of storage. Acetaldehyde accumulation in the tissue roughly paralleled the emanation of total volatiles. This increase in both cases was associated with the appearance of scald or core breakdown.

The metabolic tempo, as reflected in respiration and volatile emanation, was much greater in Bartlett pears when the fruit was ripened at 65 degrees F after approximately 6 weeks of storage at 32 degrees in comparison with that ripened at harvest. It required about 7 to 10 days less time to reach a comparable stage of senescence when the fruit was ripened after cold storage. As in fruit ripened at 65 degrees (Fig. 1), the respiratory climacteric preceded the volatile climacteric by

approximately 7 days. Acetaldehyde accumulated rapidly and reached a maximum with the appearance of severe scald and core breakdown; it then decreased rapidly with complete disintegration of the tissues and in this respect was comparable to the results reported by Harley (4). The authors interpret this correlation between acetaldehyde accumulation and the development of scald and core breakdown as confirmatory evidence in support of the conclusion of Harley and Fisher (5) as to the sequence of scald formation, namely; (a) acetaldehyde formation, (b) toxic action, (c) scald and core breakdown, and (d) water-logging of the tissue. It is interesting to note that the course of the volatile emanation closely followed the rise and fall of the acetaldehyde concentration within the fruit tissues. A considerable portion of the total volatile emanation from Bartlett pears may result from the gross liberation of acetaldehyde from the tissues. Olfactory observations, however, indicate the presence of certain volatile esters of the fatty acid series. The partition of these volatile emanations is reserved for future study.

### CONCLUSIONS

The respiratory climacteric of Bartlett pears at 65 degrees F occurs approximately 7 or 8 days earlier than does that for the emanation of volatiles. The latter is more closely associated with the presence of scald and core breakdown; it is positively correlated with the changes in the concentration of acetaldehyde within the fruit tissues. Only a mere trace of these volatiles emanate from Bartlett pears when ripened to prime dessert quality at harvest. It is only when the fruit becomes over-ripe and physiological storage disorders make their appearance that these volatile emanations increase. The tempo of both respiration and volatile emanation is increased when Bartlett pears are ripened after periods of storage at lower temperatures.

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# The Effect of Ethylene on Pectic Changes in Ripening Fruits

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THAT ethylene treatment is effective in increasing the rate of softening in fruits has been observed in previous experiments (1, 5, 6). Since the softening of the tissues during ripening has been considered to be due, at least in part, to the hydrolysis of protopectin in the cell walls to soluble pectin, it would seem reasonable to assume that ethylene has the property of increasing the rate of this reaction. In a report on preliminary work (4) this has been shown to be true. The following experiments were planned to determine the effect of ethylene upon pectic changes during the ripening of various kinds of fruits.

## MATERIALS AND METHODS

The fruits used in these experiments were obtained from the Experiment Station orchards. Unless otherwise stated samples for analyses were taken during the regular harvest season for the variety and were placed under treatment immediately after picking. The methods used in applying ethylene treatment and the handling of the untreated samples have been described in a previous publication (5).

Soluble and insoluble pectin were determined by the method of Carre and Haynes (2) on 50 gram aliquots of the fresh material, finely ground through a Russwin food chopper. Two analyses of each kind of fruit used were made: the first on the unripened fruit at time of picking, and the second when the treated fruit had reached an optimum stage of ripeness as indicated by external appearance. This period varied from 2 days for gooseberries to 14 days for the Ponderosa lemons. In the case of English walnuts, the second sample for analysis was taken when the treated lot showed definite splitting of the hulls.

## RESULTS

That ethylene treatment has a very pronounced effect upon pectic changes is shown by the results obtained in these experiments. Without exception, all of the fruits used showed definite increases in soluble pectin and decreases in insoluble protopectin content following ethylene treatment.

As can be noted in the Table I, Bartlett pears treated for an 8-day period developed approximately one and one-half times as much soluble pectin as did the untreated lot, and there was a corresponding decrease in the amount of protopectin between treated and untreated samples. Anjou pears after 12 days treatment contained nearly three times the amount of soluble pectin found in the untreated fruit. A sample of Elberta peaches was picked approximately 3 weeks before they had begun to soften on the tree. On analysis, this fruit at time of picking showed .082 per cent soluble pectin and .692 per cent protopectin. After only a 3-day period the ethylene-treated lot contained twice the amount of soluble pectin found in the untreated fruit.

TABLE I—EFFECT OF ETHYLENE ON PECTIC CHANGES IN FRUITS

Fruit	Number Days of Treatment	Soluble Pectin as Impure Calcium Pectate (Per Cent)		Insoluble Protopectin as Impure Calcium Pectate (Per Cent)	
		Treated	Untreated	Treated	Untreated
Gooseberry	0	.057	.057	1.036	1.036
	2	.316	.085	.544	.906
Panderosa Lemon (peel)	0	.098	.098	2.99	2.99
	14	.347	.110	1.90	2.80
Peach (Elberta)	0	.082	.082	.692	.692
	3	.391	.189	.332	.661
Prune (Italian)	0	.045	.045	.829	.829
	4	.196	.053	.729	.825
English walnut (Hulls)	0	.099	.099	.750	.750
	4	.232	.107	.493	.707
Pear, Bartlett	0	.100	.100	.781	.781
	8	.571	.390	.212	.483
Anjou	0	.145	.145	.930	.930
	12	.919	.331	.130	.725

A sample of Italian prunes was picked approximately 2 weeks before being fully colored. Four days after picking, the treated fruit had softened markedly and had developed nearly four times the amount of soluble pectin found in the untreated lot.

Samples of Ponderosa lemon were taken from a tree grown in the college sub-tropical greenhouse. At time of picking these fruits had nearly attained maximum size but were still green in color. Pectin analyses were made on the rind only. As can be noted in the table the rind of the treated lemons following 14 days treatment contained distinctly more soluble pectin than did that of the untreated fruit.

It is also interesting to note that the rate of protopectin hydrolysis in the hulls of English walnuts was markedly increased by the use of ethylene treatment. Sorber (7) has reported on the effective use of ethylene for the loosening of walnut hulls and similar results with pecans have been reported by Finch (3). It is apparent from the present studies not only that protopectin hydrolysis occurs during loosening of the hulls, but also that ethylene accelerates the rate of this reaction.

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## The Sulphuric Acid Oil Digestion Method for Avocados

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THERE is a need for a reliable rapid method for oil determination in avocado fruits. Lesley and Christie (4) have published on the refractometer method as related to this subject, but workers at the Florida Station (6) have found this method subject to errors ranging from 2 per cent to 40 per cent when applied to Florida grown avocados. The work here reported was therefore begun in 1935-36, and the results have been checked for two additional seasons, 1936-37 and 1937-38. The method is based on the principle of sulphuric acid digestion on which Babcock (2) based his method for the determination of butter fat in cream. Other workers have based methods of fat determination on this same principle (3, 5, 7). The range of the experiment includes Florida grown fruits of varieties of the three races of avocados, as well as three kinds of hybrids, Mexican race: Northrup, San Sebastian, Capec, Mexican seedling; Guatemalan race: Taylor; West Indian race: Trapp; and the hybrids: Winslowson (West Indian x Guatemalan, Gottfried (West Indian x Mexican), Lula (Mexican x Guatemalan). Both immature and mature fruits were included in each of the three seasons.

The procedure has been standardized and the error of the amount determined is well below  $2\frac{1}{2}$  per cent, if the precautions regarding the minimum amount of oil recovered under these conditions are observed. If an 18-gram, 6-inch size Babcock bottle is used, the size of the sample must be regulated so as to secure at least .40 gram of oil in order to reduce the error of the amount determined to 1 per cent. If the amount determined is .25 gram, the error is around 2 per cent.

The standard procedure was adopted after considering the factors, concentration of acid, the ratio of acid to amount of tissue, temperature of water bath, time of digestion, centrifuge speed, and time of centrifuging. More than 381 determinations were made during the 3 years, and each was checked against the standard ether extraction method. In order to compare results obtained by this method with those of the ether extraction method on the basis of oil quality, the refractive index, the iodine number, and Kreis' test for rancidity were determined for oil obtained by both methods from green and mature fruits of varieties of the three races and three types of hybrids. In every case Kreis' test for rancidity was negative for oils extracted by both methods. There was also close agreement in the case of the iodine number and the refractive index. Since the complete results will appear in the Journal of Agricultural Research, only the following brief summary of the procedure is presented here:

*Apparatus:*—Food chopper with peanut butter attachment; centrifuge; water bath which can be regulated at 55 degrees C; Babcock milk test bottles 8 per cent, 18-gram, 6-inch size.

*Reagents:*—Sulphuric acid C.P., sp. gr. approximately 1.84, diluted to the strength of 1.5 parts sulphuric acid to 1 part of water (1.5:1); sea sand, C.P.

*Procedure:*—Use a sufficient number of fruits so as to obtain a representative sample. Extract seeds by cutting fruit in half lengthwise, peel halves and pass avocado tissue through a food chopper with peanut butter attachment. Mix the ground tissue thoroughly and keep it in a closed container. Complete weighing operations as quickly as possible to avoid loss of moisture.

Weigh out 5- to 6-gram samples of the avocado tissue into tared 50 ml beakers. Transfer the sample into a porcelain mortar with the aid of a stirring rod. Add 5 to 6 ml 1.5-1  $H_2SO_4$  first into the beaker to collect remaining portions of the tissue and then pour into the mortar. Add 1 gram of sea sand (C.P.) and grind to a paste. Add 15 to 16 ml more of the sulphuric acid (1.5 to 1) and mix thoroughly. Transfer the resultant mixture into an 8 per cent, 18-gram, 6-inch Babcock milk test bottle. Use a funnel with a long slender neck for this purpose. Wash the mortar and pestle with three successive portions of 6 to 7 ml of acid, transferring each portion to the bottle. The Babcock bottle holds approximately 48 ml up to the neck. Therefore, the total amount of acid added would be between 38 and 43 ml, which would bring the level of the mixture to within a short distance of the bottom of the neck of the bottle. Place these bottles in a constant temperature water bath for a period of 30 minutes at 55 degrees C. The acid digests all of the avocado tissue, leaving the avocado oil.

Separate this oil from the mixture by whirling the bottles in a centrifuge equipped with Babcock-test attachment and geared to a speed of 1500 revolutions per minute, for 5 minutes. Remove the bottles, fill to the bottom of the neck with the dilute acid, whirl again for 3 minutes. Then remove the bottles, fill to the first graduation of the neck of the bottle with the dilute acid, and whirl a final time for 1 minute. Transfer the bottles back to the constant temperature water bath for a period of 10 minutes, after which the amount of oil can be read in the neck of the bottle. If the limits of the oil cannot be distinguished easily, which happens sometimes with oil from very immature fruits, this difficulty may be overcome by the addition of a few drops of the dilute acid at 55 degrees C down the side of the neck of the bottle to separate the oil from the digested portion.

*Calibration of Babcock Bottles:*—Since the Babcock bottles are calibrated to read in per cent butter fat, it is necessary to determine a factor for use in calculating the amount of avocado oil. The following procedure has been found convenient: Fill a Babcock bottle with sulphuric acid (1.5:1) so that the acid meniscus is just below the first graduation at 55 degrees C. Add avocado oil little by little until the oil approaches the first graduation. Place in a water bath at 55 degrees C for 10 minutes, transfer to a centrifuge and whirl for 3 minutes at 1500 rpm, and return to the water bath. After a period of 10 minutes read the upper meniscus of the oil. Cool the bottle to room temperature by placing the bottle under running tap water and dry the outside thoroughly with a clean dry towel. Place on analytical balance and weigh accurately to the fourth place. By means of a medicine dropper add the



oil, calibration factor of which is desired, so that it occupies from 2.5 to 5 spaces at 55 degrees C. Re-weigh and the difference in weight will be equal to the amount of oil introduced into the bottle. Place in a water bath at 55 degrees C for 10 minutes, transfer to the centrifuge for 1 minute at 1500 rpm and again place in the water bath. After an interval of 10 minutes read the upper meniscus. This reading minus the previous meniscus reading will be equal to the spaces occupied by the weighed amount of oil introduced into the Babcock bottle. From these data calculate the weight of oil contained in one Babcock space and use this as the calibration factor.

*Dry Weight Determinations:*—The amount of oil in avocados is usually expressed on a fresh weight basis for time-of-harvesting studies. If the determinations are to be expressed on a dry weight basis, 5- to 6-gram samples (in duplicate) are spread in glass weighing bottles and dried to constant weight at 62.5 degrees C in a vacuum oven. Twelve hours' drying is required to bring to constant weight under these conditions.

*Sulphuric Acid Treatment of Ether Extracted Oils:*—After the experiment was begun it was found that in the case of quite immature avocado flesh the readings were considerably higher for the ether extraction as compared with the sulphuric acid digestion method. It is known that ether extracts other substances than pure oil from plant tissues, and apparently in the case of immature avocado fruits this fraction is relatively large. It was found that when such oils were retreated with 1.5 to 1 sulphuric acid the readings were comparable to those secured by the sulphuric acid digestion method. These fat-like substances extracted with avocado oil are apparently destroyed by  $H_2SO_4$ . The following procedure was used: Samples between .75 and 1 gram of the ether-extracted oil are weighed into a Babcock bottle, and 38 to 40 cc of sulphuric acid (1.5:1) added. Shake well, transfer to a water bath at 55 degrees C for 30 minutes. Centrifuge for 5 minutes, add sulphuric acid up to the bottom of the neck, re-centrifuge for 3 minutes, add sulphuric acid up to the first graduation, and centrifuge again for 1 minute. Transfer to a water bath at 55 degrees C for 10 minutes and read the limits of the oil. Compare the results with those secured by the sulphuric acid extraction method.

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## Physiological Studies of Lemons in Storage<sup>1</sup>

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IT has long been known that the practice of storing lemons at a temperature of 40 degrees F and lower is conducive to the development of physiological disorders, such as "membranous stain" and "pitting". Higher temperatures are undesirable because they stimulate the growth of fungous parasites.

Since the effect of temperature is quite marked, it is believed that a study of the metabolism of these fruits stored at various temperatures might yield information regarding the fundamental causes of these disorders and thus aid in developing means of control.

Green California lemons were held at 32, 36, 40, 50 and 60 degrees F in the cold storage rooms at the Arlington Experimental Farm, Arlington, Virginia. Chemical analyses were made on both peel and flesh of 30 representative fruits before, during and at the end of the storage period.

### RESULTS

During the period of storage, reducing sugars showed a decrease in both the peel and flesh. The loss was greatest at the higher storage temperatures. Sucrose content was relatively low in the peel and still lower in the flesh and showed slight but inconsistent fluctuations.

Acetaldehyde determinations were made on the flesh only. As a rule, the acetaldehyde tended to increase during storage. None was found in the original sample, a slight amount in the midstorage sample and considerable quantities at the end of the storage period.

Glycosides in the peel showed irregular trends in the midstorage samples, but had definitely increased at the end of the storage period. Similarly, there was no uniformity in the total acid of the peel until the final sampling. At this period, the acid had increased at all temperatures.

None of the foregoing analyses indicates any irregularity in the metabolism which might suggest a cause for physiological disorders. A different story was obtained from the reductase studies.

Reductase activity of the peel was determined as follows: 25 grams of the ground peel were macerated by means of sand and a mortar and pestle and extracted with 100 ml H<sub>2</sub>O for 15 minutes. One ml of this filtered extract was added to 3 ml KMnO<sub>4</sub> (1.33 gram per liter) and 2 ml N/10 oxalic acid. These solutions were held at 68 degrees F until they attained an amber color. The time in minutes required to reach this end point was recorded. The results appear in Table I.

In all four of the experiments reported, the time required for the reduction of KMnO<sub>4</sub> was greatest for the fruits stored at 40 degrees F or lower. In the midstorage samples of the first experiment in 1934, the

<sup>1</sup>The writers are indebted to Charles Brooks and L. P. McColloch for making these samples available for chemical analysis and for supplying the pathological data.

TABLE I—REDUCTASE ACTIVITY (TIME IN MINUTES REQUIRED BY AQUEOUS EXTRACT OF PEEL TO REDUCE  $\text{KMnO}_4$ )

Year	Storage Temperature (Degrees F)	Weeks Stored			Disease Record at End of Storage	
		0	9	15	Total Area Affected	Fruit Showing
					Pitting (Per Cent)	Membranous Stain (Per Cent)
1935	60	9.67	5.00	3.27	29.3	19.4
	50		4.33	4.55	11.7	73.8
	40		7.33	8.75	40.0	93.3
	36		8.29	9.25	76.5	83.8
	32		9.95	8.52	60.0	6.7
1935	60	0	6	8	0 0 12.6 22.3 5.7	20.0
	50	7.66	6.37	6.25		83.3
	40		6.37	5.75		96.3
	36		6.66	7.33		30.9
	32		8.91	7.33		6.9
1934	50	0	7	13	— — —	31.4
	40	3.00	4.12	3.79		99.9
	32		5.95	5.16		6.6
			4.80	4.74		
1934	50	0	4	11	— — —	88.2
	40	6.78	6.86	5.50		91.3
	32		14.08	5.97		40.0
			9.93	7.20		

reductase activity value for 50 degrees was 4.12 as compared to 5.95 for 40 degrees and 4.80 for 32 degrees F. In the second experiment of the same year, the values for the temperatures 50, 40 and 32 degrees were 6.86, 14.08 and 9.93 respectively. During the year 1935, the temperatures studied were 32, 36, 40, 50 and 60 degrees F. In the first experiment the reductase activity values at the midstorage period averaged 4.66 for 50 and 60 degrees and 8.52 for the lower three temperatures.

In the second experiment the average for the higher temperatures was 6.37, and that for the lower was 7.74. Similar results were obtained when the analyses were made at the end of the storage period.

Where available, the disease record is also presented in Table I. It will be noted that pitting of the rind was highest at temperatures 32, 36 and 40 degrees F. While there is no direct correlation between pitting and reducing power of the peel, the same temperatures which produce the most pitting show the lowest reductase activity. It must be remembered that since reductase is expressed as the time required to reduce  $\text{KMnO}_4$ , a high figure in the table indicates low reductase activity. It would appear that some substance in the peel is oxidized more rapidly when the fruit is stored at 32, 36, 40 degrees F than when held at higher temperatures. The fact that "pits" sometimes assume a dark appearance also suggests the action of oxidases. Boiling the peel or the extract destroys its ability to reduce  $\text{KMnO}_4$  at different rates.

## SUMMARY

California lemons were stored at 32, 36, 40, 50 and 60 degrees F and analyzed for sugar, acid, glycosides, acetaldehyde and reductase activity. No relationship was found between these substances and the incidence of physiological disorders except in the case of reductase. Low reductase activity was shown by the peel of fruit stored at temperatures most conducive to development of pitting (40, 36 and 32 degrees F). Reductase activity was expressed as the time rate of reduction of standard  $\text{KMnO}_4$  solution.

## Some Associated Factors in the Development of Watercore

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THE work of Brooks and Fisher (3) has definitely shown that watercore in apples is caused primarily by high fruit temperatures induced by intense sunlight while the fruit is maturing on the tree. They also found that the affected cells possessed a higher osmotic concentration than the non-watercored cells. These conclusions were further substantiated by Fisher, Harley, and Brooks (4), when they subjected unaffected apples to heat from electric heaters or covered them with black cloth and produced watercore at will. Also, biochemical studies revealed (4) that the increased osmotic concentration of the cell sap of watercored tissues was accompanied by hydrolysis of starch grains to soluble sugars. This relatively higher sugar concentration in certain cells apparently set up local osmotic gradients until extreme turgor was established.

During the course of an investigation on the effects of leaf area, nitrogen, and soil moisture on fruit bud formation in the Delicious apple (5), an opportunity was afforded at harvest time to record the association of the above factors to the production of watercore.

### PLOT TREATMENTS

The experimental orchard consisted of a block of 135 rather uniform 13-year-old Delicious trees located at Orondo, Wenatchee Valley, Washington. The trees appeared to be vigorous, as interpreted by length of terminal growth, although the leaves were rather light green, indicating that at the time they were somewhat nitrogen deficient, no fertilizers having been applied for 2 years prior to the experiment. The soil consisted of 2 feet of clean-cultivated light sandy loam (wilting point 2.0 per cent) with underlying coarse gravel. The plots, four in number, comprised full length rows of trees, each separated from the others by a guard row. Plot 1, the check, included 28 trees and received no fertilizer; plot 2, 15 trees, had 4.5 pounds of nitrate of soda per tree, May 27; plot 3, 16 trees, 4.5 pounds of nitrate, May 27 and 4.5 pounds, July 30; plot 4, 15 trees, 4.5 pounds of nitrate, July 30 only. The nitrate was distributed in the irrigation furrows and watered in immediately. These plots were bisected by a line of irrigation faucets. One half of each plot, designated as "wet", contained those trees which received frequent irrigations and in which the soil moisture was maintained at approximately the field capacity. The other half, designated as "dry", was irrigated only after the soil had reached the wilting percentage and the trees showed definite indications of wilting. The wilting percentage was reached in these "dry" plots July 4, July 24, and September 1, respectively.

Throughout the summer branches from trees in all plots were bark ringed and leaf-fruit adjustments made to 10 large leaves per apple, 30



intensity of the sun was as identical in each plot as could be obtained under average orchard conditions. If temperature can be considered as constant, the percentage of watercore was in general directly proportional to the number of leaves per apple. Fruit on unringed branches was growing with approximately 30 leaves per apple.

Next in importance to leaf area was the influence of nitrogen when applied after terminal growth was almost or entirely completed. For a given leaf area the highest percentage of watercore was found in the nitrated plots. This held true where leaf adjustments were made to 30 and 70 leaves per apple; with 10 leaves per apple no watercore developed regardless of treatment. The effect of nitrogen also appears to be quantitative. Double applications of nitrate of soda (plot 3) showed a higher percentage of watercore than either of the single treatments. Early applications of nitrate of soda (plot 2) tended to show more watercore than later ones (plot 4), with apples from unringed branches, and with 30 leaves per apple. However, a deviation from this trend can be noted with 70 leaves per apple.

TABLE I—EFFECTS OF LEAF AREA, SOIL MOISTURE, AND NITRATE OF SODA ON THE DEVELOPMENT OF WATERCORE IN DELICIOUS APPLES

Leaves per Apple	Plot I		Plot II		Plot III		Plot IV	
	Check No Fertilizer		4.5 Pounds Ni- trate of Soda May 27		4.5 Pounds Ni- trate May 27 + 4.5 Pounds Ni- trate July 30		4.5 Pounds Ni- trate of Soda July 30	
	"Wet" (Per cent)	"Dry" (Per Cent)	"Wet" (Per Cent)	"Dry" (Per Cent)	"Wet" (Per Cent)	"Dry" (Per Cent)	"Wet" (Per Cent)	"Dry" (Per Cent)
10 . . . . .	0	0	0	0	0	0	0	0
30 . . . . .	2.1	0	8.3	9.0	17.3	10.2	7.0	5.2
70 . . . . .	12.0	12.5	37.4	43.1	45.8	47.5	28.6	40.0
Unringed, approximately 30	1.1	1.5	2.8	4.6	3.4	5.6	2.0	1.9

The influence of soil moisture on watercore development was not as clear cut as either leaf area or nitrogen, although for the most part more affected fruits were present in the "dry" plots. This held particularly true for the 70 leaf and unringed fruits.

#### DISCUSSION AND CONCLUSIONS

Results secured in this study offer evidence that factors intimately associated with carbohydrate metabolism in the leaf are instrumental in predisposing the fruit tissues to watercore. This in no way detracts from the validity of previous investigations (4), where watercore in apple fruit tissues was found to be the ultimate effect of rapid starch hydrolysis in localized tissues actuated by comparatively high fruit temperatures, but it does help to explain the difficulty at times to account fully for the incidence of watercore in the field.

Orchards or individual trees of a given variety and in the same general locality may show considerable variation in the extent of the disorder. According to the results of the present experiment such a variability might be accounted for in part by either differences in leaf-fruit ratios, nitrogen content of the leaves, or both.

Apparently the factor predisposing an apple to watercore is primarily the photosynthetic activity of the leaf for no fruits have been observed to develop watercore after their removal from the tree. If sufficient carbohydrate has been synthesized and transported to the fruit, it is then probably rendered subject to the action of high temperatures, subsequent starch hydrolysis, and resultant watercore. Brooks and Fisher (3) pointed out that large apples tended to watercore more readily than those of lesser size and susceptibility to the condition increased as the fruit approached maturity on the tree.

Leaf-fruit ratios on ringed branches are undoubtedly not strictly comparable to those on unringed branches. This is evidenced in Table I when the percentages of watercore on ringed branches with 30 leaves per apple are compared with those on unringed branches. The unringed branches had approximately 30 leaves per apple, although in most cases they showed less watercore than the ringed branches with similar leaf areas. The differences between 10, 30, and 70 leaves per apple, however, are so well defined that the fundamentals relating to watercore incident should be equally applicable to unringed branches, although a higher leaf-fruit ratio would probably be required to equal the carbohydrate content of those ringed. Ballard, Magness, and Hawkins (1) in 1919-20, observed that Yellow Newtowns on girdled branches had a marked tendency to watercore, and that fruits from girdled limbs were significantly higher in total sugars than those from untreated branches.

The influence of nitrogen in the development of watercore is probably one of increasing the efficiency of leaves to synthesize carbohydrates. According to Batjer and Degman (2) carbon dioxide assimilation per unit area of leaf doubled within a 7-day period following nitrogen applications to young apple trees in sand cultures, growing at a low nitrogen level; and 21 days after application, assimilation had increased fourfold.

As shown in Table I, nitrate of soda accelerated the development of watercore only when a sufficient leaf area was present to provide the required carbohydrates. This acceleration, however, might be quite important for in Table I and Fig. 1 the percentage of watercore in the average of both "wet" and "dry" divisions of Plot 3 (double nitrate) with 30 leaves per apple, was comparable to Plot 1 (no nitrate) with 70 leaves per apple.

Applications of nitrate of soda to the soil significantly increased the percentage of watercore under the conditions of this experiment in all but the plots having 10 leaves per apple. Regardless of this apparently conclusive evidence, it is recognized that the correlation of nitrogen and watercore might be governed by the nutritional status of the tree. Trees already having a high level of fertility may respond to additional nitrogen applications in quite a different manner than trees having a low level, insofar as watercore initiation is concerned. It has been commonly observed that apples color poorly and mature later in the season on trees having a rather high nitrogen content. Since watercore is correlated with advancing maturity of fruit (3), and since total sugar content of the fruit shows an ascending gradient with increased color



(6), it is very possible that watercore development could actually be retarded if nitrogenous fertilizers were applied to trees already having a sufficient supply of this element.

Careful consideration should also be given to the fact that in the present plots trees did not receive nitrate of soda before May 27. This time of application was probably too late to appreciably influence extension growth or the total leaf area. Had the nitrate been applied in winter or early spring, the increased vegetative growth response would undoubtedly have caused a greater reduction of carbohydrate reserves in the tree. Such a change in the carbohydrate level, along with the added mechanical protection of the additional growth in providing shade from the sun's rays, might tend to lessen the probability of watercore development. Brooks and Fisher (3) found that trees fertilized with nitrate of soda, over a 4-year period, made a greater terminal growth than those receiving no nitrogen, and these nitrated trees in most cases produced the lowest percentage of watercore.

Therefore, under the conditions of the present study, with trees appearing to be somewhat deficient in nitrogen, it is concluded that the higher percentages of watercore found in the nitrated plots, were probably the result of an increase in leaf efficiency, through the stimulus of added nitrogen, to synthesize and transport carbohydrates to the fruit.

In accord with the findings of Brooks and Fisher (3), abundance of soil moisture appeared in no way to be related to the prevalence of watercore. In many instances the highest percentages of water-cored apples were found in the "dry" plots.

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## Effect of Certain Waxing Treatments at Time of Harvest upon the Subsequent Storage Quality of Grimes Golden and Golden Delicious Apples<sup>1</sup>

By C. W. HITZ and I. C. HAUT, *University of Maryland, College Park, Md.*

**A**N undesirable feature of picking Grimes apples prematurely has been the tendency of that variety to wilt excessively under normal conditions of cold storage. Hesse and Hitz (3) have recently suggested that the limits at which Grimes may be harvested and still develop standard storage qualities are wider than for some other varieties. If, by some treatment previous to cold storage, Grimes apples could be protected against an excessive moisture loss, the picking season for this variety could be considerably extended to the ultimate benefit of the commercial grower.

Studies of a preliminary nature have been undertaken for the last 3 years in an effort to control wilt in this variety by applications of wax before storage. Magness and Diehl (5) in a somewhat similar study with late fall varieties concluded that any paraffin application heavy enough to materially reduce weight loss caused the fruit to develop an undesirable flavor after a period in storage. Smock (7) using a wax emulsion, described by the manufacturer as number 489D, found that wilting was decreased by applications of the full and half strength wax. He described an undesirable alcoholic flavor developing in the waxed Yellow Newtown apples after 25 days exposure to 67 degrees F. However, he suggested, particularly for pears, that "a light coating of wax would sufficiently delay ripening at a storage temperature of about 45 degrees F to warrant its use".

This report concerns the application by dipping of the Brytene wax emulsion 489A diluted with two parts of water in relation to wilting and storage behavior of Grimes Golden and Golden Delicious apples gathered at different harvest periods.

### STUDIES IN 1936

Samples of Grimes Golden apples in 1936 were selected in conjunction with a maturity study in progress at the station, and the fruits selected were from the storage samples of the maturity studies. Therefore, the samples were composed of apples from 16 trees from eight orchards throughout Maryland. Storage samples were collected once weekly starting August 25 and continuing through September 11. The August 25 and August 31 samples were treated as follows: 1/6 bushel untreated, that is placed in cold storage at time of picking; 1/6 bushel packed in glassine bags and placed in cold storage; 1/6 bushel waxed and placed in cold storage. The samples of September 4 and September 11 were not given the treatments of the preceding dates. They were

<sup>1</sup>Scientific Contribution No. 488, Department of Horticulture, Maryland Agricultural Experiment Station.

placed in cold storage immediately after picking. On September 14 a peck from the storage sample of each tree from each orchard was taken from cold storage, exposed to a temperature of 65 degrees F in a closed storage room. They remained here for 15 days or until, in the opinion of the authors, they were in prime eating condition. On that date 12 of the fruits from each orchard, six from each of the two trees, were waxed and placed in cold storage. In January the per cent wastage in these fruits was compared with that of the fruits stored immediately.

The results of the treatments given the first two pickings are presented in Fig. 1. Waxing reduced the amount of wilt, but the waxed fruits developed scald. The waxed samples of the two dates developed scald to about the same extent, although the scald development seemed concerned with maturity since the unwaxed fruits picked August 25 developed 20.7 per cent scald whereas no scald developed on the unwaxed samples of August 31.

The results of the treatments given the September 4 and September 11 pickings are also presented in Fig. 1. No scald developed on any lot regardless of treatment; the waxed samples, however, were pre-ripened 19 days before they were waxed. It is shown that holding the fruits at a temperature of 65 degrees F until ripe and then waxing had reduced the amount of wastage during the subsequent storage life of the fruit. The pre-ripened, waxed apples showed less wilt on the examination date than did those placed immediately in cold storage or those pre-ripened unwaxed fruits placed in cold storage. Although there was an increase in wilt of the pre-ripened waxed fruits over those

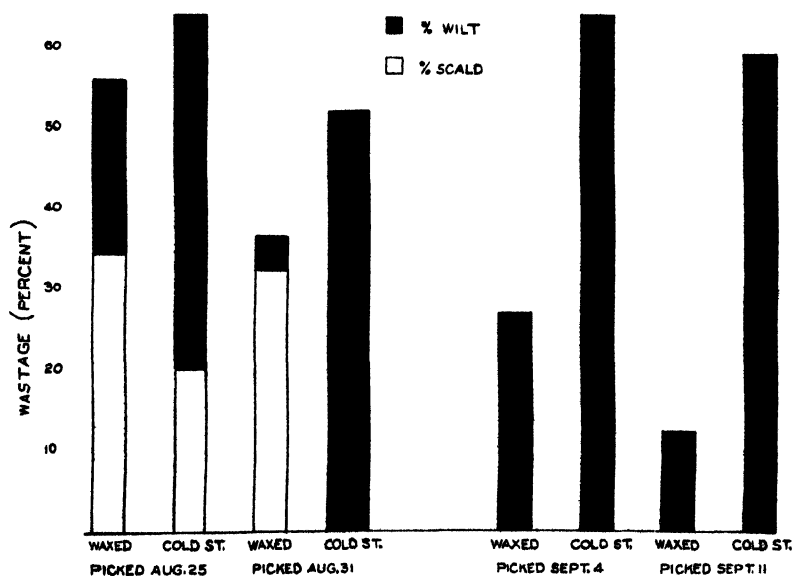


FIG. 1. Per cent wastage in January on cold storage samples waxed immediately after picking, samples of August 25 and August 31, on cold storage samples waxed after pre-ripening, samples of September 4 and September 11, and on samples placed in cold storage immediately after picking, 1936.

waxed immediately after picking, the reduction in scald in the former reduced the total wastage.

### STUDIES IN 1937

In 1937 two samplings of Grimes were made. The first was selected September 8, directly from the orchard and the second lot was selected September 15 from fruits on the packing house floor. Both samples were from the University Orchard at College Park.

Fruits of each sampling date were divided into six lots and placed in a room at 57 degrees F for various periods before the waxing treatment. Lots, treatments, number of fruits treated and placed in cold storage, and the total wastage at the January 22 storage examination are given in Table I. None of the fruit was washed before waxing and

TABLE I—EFFECT OF WAXING ON FRUIT WASTAGE

Picking Date	Waxing Date	Number of Days Common Storage Before Waxing	No Fruits Placed in Storage	Total Wastage January 22
September 8	Not waxed	0	74	28.4
September 8	September 8	0	69	58.0
September 8	September 15	7	40	2.5
September 8	September 22	14	34	14.7
September 8	September 28	20	27	37.
September 8	October 14	36	27	92.6
September 15	Not waxed	0	73	32.9
September 15	September 15	0	69	18.9
September 15	September 22	7	46	6.5
September 15	September 28	13	50	42.
September 15	October 14	29	33	48.5
September 15	October 20	35	38	42.1

the check fruit was packed in oiled paper. All samples were placed in  $\frac{1}{2}$ -bushel peach hampers which were placed in orchard lugs during the storage period. This method of packing undoubtedly increased ventilation in comparison with commercially packed fruit.

Total wastage is composed of the fruits considered unsaleable due to wilt, scald or rot. The relative importance of these components is presented in Fig. 2.

It is apparent that waxing immediately after picking controlled the amount of wilt in comparison to the unwaxed samples, but encouraged materially the development of scald. Holding the fruit for 7 days at 57 degrees F before treatment succeeded in reducing the amount of wilt in comparison with the unwaxed cold-storage sample, averted the development of scald in comparison with the immediately waxed cold-storage lot, and greatly reduced the percentage of wastage in comparison with either. The waxed fruit did not develop scald if it had been held at the higher temperature before waxing, but holding the fruits longer than 7 days before treatment resulted in a great increase in wastage over the 7 day period, and generally, over the fruits of the check or the unwaxed treatment. Table I and Fig. 2 indicate little influence of maturity on the results since the unwaxed sample of neither picking date had consistently better storage quality.

After the grading of January 22, the good apples from the various lots were placed again at a temperature of 57 to 60 degrees F until February 11. At the end of this second ripening period, those apples

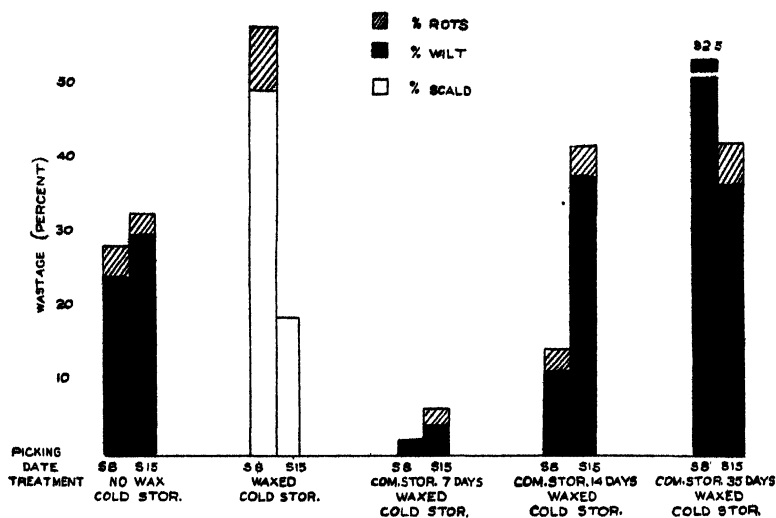


FIG. 2. Per cent wastage in January for waxed and unwaxed samples of Grimes of two picking dates given various pre-ripening periods in common storage before treatment, 1937.

held at this high temperature for more than 1 week before treatment were in an advanced stage of over-ripeness and mealy breakdown was prevalent. The check consisting of unwaxed samples from cold storage were also slightly over-ripe. Those lots which were waxed immediately after picking, and those which were held 1 week before waxing were, by observation, in the best physical condition, except for scald, and had the best flavor. As in the examination on January 22, those fruits which had been waxed immediately showed scald, but the flavor was not seriously affected. Those samples delayed 1 week before waxing showed no scald development, but an increased wilt and rot over those immediately waxed.

Waxing reduced the tendency of the variety to yellow in color when exposed to room temperatures. The fruits which were waxed immediately after picking did not develop an attractive yellow color even after the period of exposure to 57 to 60 degrees F following cold storage. Although there was lack of uniformity in the ground color of those delayed 1 week, they presented a much more attractive appearance at the end of the storage period at the high temperature than those waxed immediately. The unwaxed check samples had developed a high yellow color at the high temperature following cold storage. Samples delayed 2 weeks or more before waxing developed a high color before the wax application and presented the best appearance throughout the storage period of the experiment, but soon lost their attractiveness in the high temperatures following the period of cold storage.

Palatability tests in January did not reveal any alcoholic flavor in the fruits ripened 1 week or more before waxing and placing in cold storage. Those fruits waxed immediately after picking had a peculiar flavor which could have been termed alcoholic. Following a similar test

after the common storage period of January 22 to February 11, it was concluded that the fruits waxed immediately after picking and those waxed following a pre-ripening of 1 week had the best flavor. They were not as over-ripe as were the fruits of all other treatments and no objectionable alcoholic taste could be detected.

### STUDIES IN 1938

In 1938 these studies were expanded to include the Golden Delicious variety since it is known to wilt badly under certain conditions of storage and maturity. Samples, therefore, were taken from one Golden Delicious orchard in addition to samples from two Grimes orchards. Six samplings were made from a commercial Grimes orchard, hereafter designated as Grimes orchard No. 1, four samplings from Grimes trees at the University orchard, designated hereafter as Grimes orchard No. 2, and four from a commercial Golden Delicious orchard. Sampling was done weekly beginning on August 16 in Grimes orchard No. 1, August 22 in Grimes orchard No. 2, and on August 30 in the Golden Delicious orchard. About 3 bushels of apples were picked at random from at least 10 trees in each orchard on every picking date. The fruits were divided into eight representative lots, and given the following treatments:

Lot	Treatment of Samples Prior to Cold Storage	Amount of Fruit (Bushels)
A	Waxed on date of picking	$\frac{1}{2}$
B	Not waxed	$\frac{1}{2}$
C	Held 1 week at 60 degrees F, then waxed	$\frac{1}{4}$
D	Held 1 week at 60 degrees F, not waxed	$\frac{1}{4}$
E	Held 2 weeks at 60 degrees F, then waxed	$\frac{1}{4}$
F	Held 2 weeks at 60 degrees F, not waxed	$\frac{1}{4}$
G	Held 3 weeks at 60 degrees F, then waxed	$\frac{1}{4}$
H	Held 3 weeks at 60 degrees F, not waxed	$\frac{1}{4}$

To compare changes in weight during storage of fruits from the different treatments, 10 apples from each lot were marked and weighed the day of picking. These fruits were again weighed at the time of removal from 60 degrees F, and at 5 weeks and 12 weeks after picking. Fruit was weighed and examined at 5 and 12 weeks from date of picking so that the fruits picked at the different dates would be in cold storage the same length of time. This procedure removed the influence of length of cold storage period on the physical and chemical changes and development of storage disorders. With a Magness and Diehl (6) color chart, ground color was determined at every weighing. Since the chart does not have a yellow corresponding to a full ripe stage,  $4\frac{1}{2}$  was taken to represent this stage. A qualitative starch test (2) was made on representative apples at time of picking, at time of removal of 60 degrees F, and at the 5 weeks examination. Starch tests at the end of 12 weeks of storage showed that all starch had disappeared from the samples regardless of treatment.

At the end of the 5- and 12-weeks period the average weight loss, in grams per 1,000 grams original weight, for the number of picking periods were computed for all orchards. The weight changes of the

Golden Delicious were analyzed by analysis of variance for the effects of immediate and delayed storage for 1 week on waxed and unwaxed samples. On the samples of Grimes orchard No. 1, weight changes during the 5- to 12-weeks period were analyzed by the same method. Standard error of the means for the samples of the other orchards allowed less detailed comparisons, and some comparisons were made by "Student's" method.

The results presented in Table II show that waxing immediately after picking or after 1 week of pre-ripening significantly reduced the weight loss in either waxed sample over its accompanying unwaxed sample regardless of treatment before waxing. As indicated by the high standard error values for the total weight loss at 12 weeks, samples pre-ripened for 2 weeks or more showed high variability between picking dates. Isolating this variability by "Student's" method of comparison of the waxed and unwaxed samples revealed that the waxing still retained its significance in averting weight loss. By the same method of analysis, the samples treated immediately after picking or pre-ripened 1 week prior to treatment designated to waxing greater significance than did comparison of means. Waxing reduced the rate of weight loss as is shown by the differences in the waxed and unwaxed samples during the storage period of 5 to 12 weeks after picking. Again "Student's" method revealed differences not shown by comparison of means, and analysis of variance proved waxing to have a high significance. In many cases the rapid loss in weight of the unwaxed samples over the waxed samples enabled fruits waxed after 2 or 3 weeks of pre-ripening to have a smaller weight loss at the end of 12 weeks than the unwaxed fruits placed in cold storage immediately after picking. However, some unwaxed Grimes which had been pre-ripened for 2 or 3 weeks did not show significantly greater weight loss than the unwaxed samples placed in cold storage immediately, and both unwaxed Grimes and Golden Delicious apples pre-ripened 1 week showed the same effect. Although the exact cause for this was not completely isolated, it was due probably to excessive air movement in cold storage, a fan-cooled room, to a more rapid sealing over of the broken lenticles (1) at the higher temperature of the pre-ripening period, or to an influence of the climacteric (4). The weight losses in the unwaxed samples during the 5- to 12-weeks period showed an inverse relationship between storage loss and length of pre-ripening period, and may have indicated some functional change in the apples prior to cold storage. The differences in loss of samples from Grimes No. 1 during the 5- to 12-week period that were due to length of pre-ripening period reached the 5 per cent point in analysis of variance methods.

Although the data from fruits of September 7 caused sampling dates to reach the 5 per cent point in significance, it would appear, as revealed by analysis of variance, that maturity had little influence upon the weight loss of Golden Delicious at any storage period. The weight losses at any period in the samples of Grimes from orchard No. 1 seemed to be influenced by the picking date. Observation showed a minimum loss on August 30 followed by significant increases before and after that date. Changes during the 5- to 12-weeks period that

TABLE II—WEIGHT LOSS, STARCH-IODINE NUMBER AND GROUND COLOR CHANGES AT THREE STORAGE EXAMINATIONS FOR WAXED AND UNWAXED GRIMES GOLDEN AND GOLDEN DELICIOUS GIVEN VARIOUS PRE-RIPENING TREATMENTS BEFORE COLD STORAGE

Treatment	Common Storage			End of 5 Weeks			End of 12 Weeks			5 to 12 Weeks Storage Period		
	Weight Loss per 1000 Grams Original Weight	Starch-Iodine Number	Ground Color Change	Weight Loss per 1000 Grams Original Weight	Starch-Iodine Number	Total Ground Color Change	Weight Loss per 1000 Grams Original Weight	Total Ground Color Change	Weight Loss per 1000 Grams Original Weight	Total Ground Color Change	Ground Color Change	
Grimes Orchard No. 1												
Waxed immediately	—	—	—	15.6±1.7	5.9	2	29.5±2.8	4	14.0±1.7	2	2	
Not waxed	—	—	—	29.0±4.0	7.0	7	48.7±8.7	1.2	22.0±4.4	5	5	
Pre-ripened 1 week waxed	11.2±4.9	1.0	.3	22.2±5.6	8.7	.3	35.2±6.4	.9	11.9±2.2	.3	.3	
Pre-ripened 1 week not waxed	11.2±4.9	1.0	.3	29.2±4.6	8.9	.9	47.7±7.9	1.8	19.9±3.7	.9	.9	
Pre-ripened 2 weeks waxed	19.0±4.3	5.4	1.0	27.4±5.2	8.9	.5	38.8±6.4	.8	12.2±1.3	.3	.3	
Pre-ripened 2 weeks not waxed	19.0±4.3	5.4	1.0	31.0±5.1	9.0	1.0	49.4±7.7	2.4*	19.3±3.2	.3	.3*	
Pre-ripened 3 weeks waxed	26.4±2.7	8.5	1.8	31.4±3.0	9.0	.3	47.2±8.8	2.2	13.1±2.1	.3	.3	
Pre-ripened 3 weeks not waxed	26.4±2.7	8.5	1.8	32.0±4.4	9.0	.6	50.7±10.0	2.4*	18.0±5.3	—	.0*	
Grimes Orchard No. 2												
Waxed immediately	—	—	—	18.6±2.2	6.6	2	32.2±4.9	.5	13.6±2.0	3	3	
Not waxed	—	—	—	30.0±5.3	7.4	.6	49.5±6.8	.9	19.4±2.8	.3	.3	
Pre-ripened 1 week waxed	10.0±3.0	0.9	.4	21.2±2.6	8.5	.8	33.3±4.0	1.1	11.8±1.3	.2	.2	
Pre-ripened 1 week not waxed	10.0±3.0	0.9	.4	27.6±3.3	8.6	1.0	44.9±7.9	1.7	16.0±1.7	.6	.6	
Pre-ripened 2 weeks waxed	21.9±3.4	4.9	1.0	30.5±1.7	8.9	1.5	41.1±2.2	1.6	10.6±1.2	.1	.1	
Pre-ripened 2 weeks not waxed	21.9±3.4	4.9	1.0	34.3±3.2	9.0	2.2	50.7±5.3	2.4*	16.8±3.8	.2*	.2*	
Pre-ripened 3 weeks waxed	36.6±1.1	8.8	1.8	40.5±0.8	9.0	2.0	53.3±10.0	2.2*	12.8±1.2	.1	.1	
Pre-ripened 3 weeks not waxed	36.6±1.1	8.8	1.8	43.2±.8	9.0	2.2	59.0±12.0	2.4*	15.9±2.4	.2*	.2*	
Golden Delicious												
Waxed immediately	—	—	—	23.6±2.6	—	0	44.9±4.4	.0	21.2±3.4	.0	.0	
Not waxed	—	—	—	34.8±2.3	—	.5	63.5±4.8	.6	28.7±4.3	.1	.1	
Pre-ripened 1 week waxed	14.9±2.8	—	.3	31.3±1.5	—	.5	51.4±2.0	.5	20.3±2.9	.0	.0	
Pre-ripened 1 week not waxed	14.9±2.8	—	1.2	—	—	1.4	—	1.4	—	.0	.0	
Pre-ripened 2 weeks waxed	14.9±2.8	—	.3	39.5±0.3	—	.8	67.1±3.2	1.3	27.0±4.1	.5	.5	
Pre-ripened 2 weeks not waxed	14.9±2.8	—	1.2	—	—	1.7	—	1.7	—	.1*	.1*	
Pre-ripened 3 weeks waxed	35.9±4.3	—	1.4	41.8±5.1	—	1.8	62.7±9.2	1.6	21.0±5.7	.0	.0	
Pre-ripened 3 weeks not waxed	35.9±4.3	—	1.4	44.2±5.8	—	1.8	72.2±9.4	1.9*	28.0±5.0	.1*	.1*	



were due to the effect of dates reached the 1 per cent point as shown by analysis of variance. Although there may have been a possible significant influence of dates, there was no indicated trend in the samples from the other Grimes orchard.

As revealed in Table II, waxing influences starch loss only in the fruits stored immediately. The probable greater respiration of the fruits given the longest pre-ripening treatment had lead to almost complete exhaustion of the starch reserve. Otherwise, as shown by the iodine-starch reaction test, waxed apples lost starch at the same rate as the unwaxed fruits given the same storage treatment.

Waxing, however, did retard the development of yellow color. In all cases the ground color of the waxed fruits at the 12-week examination was dependent upon the color of the fruit at the time it was waxed and placed in cold storage. The yellow color was always more intense in the unwaxed samples than in the waxed samples given the same treatment and picked at the same time. There was a change in ground color of the fruits at time of picking due to the influence of maturity of the fruit. The change from the first to the last date of picking was not large for any orchard.

Although no edibility tests were planned for the 12-week examination, inconclusive sampling did not indicate the development of an alcoholic flavor in any of the samples.

#### DISCUSSION AND CONCLUSIONS

Smock (6) and Magness and Diehl (5) reported that waxing keeps the fruit in better physical conditions but that alcoholic flavors, a poor ground color development and an internal browning may result. Contrary to the results of Smock (7) with the Yellow Newtown variety this investigation shows that waxing Grimes immediately after picking encourages rather than inhibits scald.

Waxing fruits materially reduced the percentage of wilt and loss in weight of apples given any pre-ripening treatment. Waxing the fruits after 1 week of pre-ripening resulted in decreased wastage over fruits placed in cold storage immediately after picking. The results also showed that pre-ripening Grimes for 1 week at 57 to 60 degrees before waxing averted the development of undesirable flavors hitherto reported to accompany waxing. Whether or not treatment for any period of less than 1 week's duration would be efficacious, as well as the effect of various temperatures and wax concentrations is now being determined. The data herein reported are considered of a preliminary nature and more extensive work is in progress.

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## Response of Howard 17 Strawberry to Sodium Salts<sup>1</sup>

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**I**N experiments conducted at the Experiment Station at Durham, New Hampshire, since 1922, sodium nitrate in some years caused a marked reduction in yield of Howard 17 strawberries. Some of this data has been presented in a previous paper (3). At no time has a significant increase in yield resulted from applications of sodium nitrate. In these tests each treatment was replicated three or four times.

The soil, which is classed as Gloucester stony loam<sup>2</sup> underlaid at a depth of from 18 to 36 inches with an impervious gray till varies markedly in depth and texture in the plots used in the experiments. It has been observed that soil differences in several parts of the field account for greater differences in yield than can be accounted for by chemical treatments in some of these tests.

It should be emphasized here that the sodium nitrate injury referred to must not be confused with so-called nitrogen injury to the crop reported by some authors. It was the writer's opinion that in the New Hampshire tests something other than nitrogen caused the injury in plots where sodium nitrate was applied 2 to 3 months following planting, since the leaves of affected plants were somewhat dwarfed and showed none of the dark green foliage or increased growth characteristic of plants supplied with large amounts of nitrogen.

Hoagland and Snyder (2) investigated the effect of sodium salts on Nich Ohmer and Banner strawberries grown by water culture methods. Sodium chloride and sodium sulphate were toxic to the Nich Ohmer variety even at concentrations of 500 parts per million. This variety was considered sensitive to concentrations of even 100 to 500 parts per million. Sodium bicarbonate caused some yellowing of foliage but less leaf scorch than was produced by sodium chloride or sulphate. The pH of toxic solutions ranged from 7.3 to 8.2. The Banner variety was much less sensitive to injury from all sodium salts. The Nich Ohmer strawberry had a higher capacity than Banner for sodium accumulation in the leaf.

It was considered of interest to probe further the question of reduced yield occurring in some seasons due to sodium nitrate application. Considering the error in fertilizer tests caused by soil heterogeneity it was deemed advisable to use smaller individual plots and a larger number of replications than formerly for each treatment. Fisher's Analysis of Variance was applied to the results.

### NEW HAMPSHIRE EXPERIMENTS

In May 1934 a field was set to Howard 17 strawberry plants according to the matted row system of culture. In order to determine the cause of injury to Howard 17 strawberries when sodium nitrate was

<sup>1</sup>Scientific Contribution No. 70 of the University of New Hampshire.

<sup>2</sup>From the results of recent soil investigations it is possible that this soil type may be reclassified and its terminology revised.

applied to the soil, the following experiment was planned in such a way that the results could be subjected to statistical analysis. For this purpose the planting was divided into 1/500 acre plots so that there were 36 repetitions of each treatment.

Chemicals were chosen for comparison in such a way that each of the cations Na, Ca, and  $\text{NH}_4$  could be combined separately with  $\text{NO}_3$ ,  $\text{PO}_4$ , and  $\text{SO}_4$ . In this way the effect of sodium ion could be determined in the presence of each one of the anions and also with the salts in which sodium was absent. Standard chemical fertilizers were utilized as far as possible, otherwise chemically pure chemicals were used. Table I indicates the various combinations and dates of application.

The fertilizers and chemicals were applied as shown in Table I either on July 25 or August 8, at which time three to four runner plants per parent plant had already formed. This was approximately 10 per cent of the total number formed during the season. Care was taken to apply these materials so that they did not come in direct contact with the strawberry plants, and so that it was distributed evenly over the soil area expected to be occupied at the end of the growing season. There was sufficient rain immediately following the July 27 application to dissolve and wash the chemicals into the soil, 1.05 inches being recorded on the following day. The soil was fairly moist at the time of the August 8 application. Light rains occurred on August 13, 16, and 23, and 0.57 inch on August 24. Doubtless the salts had become incorporated into the soil before any other runners had taken root. After August 25 runner formation was more rapid, 50 per cent being formed between September 5 and 10. About 90 per cent of runners formed had taken root by October 1. The chemical materials were purposely added in rather large amounts.

TABLE I—CHEMICALS APPLIED TO HOWARD 17 STRAWBERRIES  
(1934, 1936, 1938)

Material	Source of Material	Rate Applied Per Acre (Pounds)	Date Applied*		
			1934	1936	1938*
1. $\text{NaNO}_3$ .....	Sodium nitrate	400	August 8	August 17	May 5
2. $\text{NaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}$ .....	C. P. Chemical	600	August 8	August 17	May 5
3. $\text{Na}_2\text{SO}_4$ .....	C. P. Chemical	325	August 8	August 17	May 5
4. $\text{NH}_4\text{NO}_3$ (+ $\text{CaCO}_3$ ) .....	Calnitro	300	July 25	August 17	May 5
5. $\text{NH}_4\text{H}_2\text{PO}_4$ .....	Ammo-phos	600	July 25	August 17	May 5
6. $(\text{NH}_4)_2\text{SO}_4$ .....	Ammonium sulphate	300	August 8	August 19	May 5
7. $\text{Ca}(\text{NO}_3)_2$ .....	Calcium nitrate	425	July 25	August 19	May 5
8. $\text{CaH}_2(\text{PO}_4)_2 \cdot \text{H}_2\text{O}$ (+ $2\text{CaSO}_4 \cdot \text{H}_2\text{O}$ ) .....	Superphosphate	1,500	August 8	August 19	May 5
9. $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ .....	Gypsum	400	July 25	August 19	May 5
10. Check .....	Nothing	0			

\*In 1934 and 1936 these materials were applied to strawberries planted in May of the same year and in 1938 to a planting made in May 1937.

Table II indicates the yields for 1935 obtained with the different treatments of 1934. In every case where sodium was present the yield was significantly less than in the check plots or where ammonium salts had been used. A slightly reduced yield occurred as the result of calcium nitrate fertilization. There was no significant difference in yield

between the check plots and the ammonia, gypsum or superphosphate plots. It was very noticeable that plants were stunted where sodium salts had been used. This was indicated by short petioles and small leaves. One may question whether plots may have been affected by fertilizer application in adjacent plots. That this did not happen was indicated by the fact that there was a sharp line of demarkation in visible plant characteristics between plots exactly where a change was made in the fertilizer used. For example, the stunting effect of sodium salts ceased abruptly at the end of plots where application of this type of material had been made and ammonium salt fertilization commenced.

TABLE II—EFFECT OF SALTS ON STRAWBERRIES

Treatment		Yield Per Acre (Kilos)			Leaves		Petioles	
					Area Per Leaflet (Sq. In.)	Weight Per Leaf (Grams)	Length (Feet)	
Cation	Anion	1935	1937	1938	1937	1938	1937	1938
Na	NO <sub>3</sub>	1,110*	2,095*	2,396*	1.76*	1.44	.46*	.69*
	PO <sub>4</sub>	1,012*	2,224*	3,625*	1.58*	1.35	.49*	.62
	SO <sub>4</sub>	1,149*	2,491*	3,468*	1.85*	1.21*	.51*	.54*
NH <sub>4</sub>	NO <sub>3</sub>	1,466	2,990	2,459*	3.38	1.76*	.73	.80*
	PO <sub>4</sub>	1,531	3,334*	2,450*	3.77*	1.87*	.77*	.84*
	SO <sub>4</sub>	1,432	3,296	1,924*	3.36	1.77*	.72	.79*
Ca	NO <sub>3</sub>	1,242*	3,056	2,545*	3.56	1.56*	.71	.74*
	PO <sub>4</sub>	1,361	3,387*	3,515	3.24	1.41	.72	.63
	SO <sub>4</sub>	1,457	3,189	3,712	3.38	1.37	.71	.59
Check		1,495	3,037	3,812	3.20	1.41	.71	.61
Minimum differences between treatments to be significant		217	304	348	0.47	0.11	.035	.05
P† for odds 99 to 1		2.17	3.40	2.56	3.40	2.56	3.40	2.56
P† found		5.87	19.19	27.89	24.75	31.57	91.22	40.00

\*Differences from the check that are significant.

†If the P found is as large or larger than that indicated for the necessary odds, it may be concluded that the treatments have had a significant effect upon the characteristic in question. (5)

The experiment was repeated on a planting made May 1936 with 1/500 acre plots and 22 replications of each treatment. The same treatments were used as in 1934 and fertilizer application made on August 17 and 19, 1936; 0.85 inch of rain occurred August 22. Again the yield was reduced where sodium salts were used. A significant increase in yield was obtained with Ammo-phos and with superphosphate while calcium nitrate did not have the depressing effect noted in 1935.

In addition to yield, measurements were made of leaf area and petiole length just before harvest in 1937. The latter characteristic has been considered an especially reliable indication of plant vigor (1). Wherever sodium salts were used there was a reduction in leaf area of 42 to 50 per cent of that of the plants in check plots. There was an increase of 18 per cent in leaf area in Ammo-phos plots. These differences in leaf area correspond to differences obtained in yield from the same plots. There was no increase in leaf area on the superphosphate plots,

however, although yield was increased significantly. Leaf area was measured with the apparatus described by Potter (4).

Table II shows also the effect of minerals on petiole length. The results correspond closely with those obtained for leaf area with relation to increases and decreases in yield when compared with check plots where fertilizer was applied in the non-bearing year.

It is the practice of some growers to apply fertilizer to the strawberry bed previous to bloom in the crop year. It was therefore deemed of interest to make a test with the same minerals used in the previous two tests to determine what effects might be obtained with application to the plants previous to bloom in spring. Minerals were applied at the same acre rate as in previous years to 1/350 acre plots with 15 replications of each treatment. Application was made May 5, 1938, and the fertilizer broadcast over the matted rows. The salts were brushed from the foliage after application to prevent injury to the leaves by direct contact. Light rain occurred May 7 and 0.51 inch of rain on May 12. Tables II and III show the striking differences between the response of strawberries fertilized at this time and those to which fall applications had been made in previous years. The yield was markedly depressed wherever nitrogen had been included in the fertilizer, varying from a 33 per cent reduction with calcium nitrate to 50 per cent reduction with ammonium sulphate. The yield was reduced slightly in the sodium sulphate plots. Yields from the sodium acid phosphate plots were not significantly different from yields in the check plots. The same may be said of superphosphate. The reduction in yield with ammonium sulphate was significantly more than with other nitrogen compounds. Reduced yield where ammonium salts were used seemed to be the result of greatly increased vigor of plants as indicated by larger leaves and longer petioles. With calcium nitrate there was also an increased leaf weight but not to the extent found with ammonium salts in which case leaf weight was increased two to three times as much. Although

TABLE III—EFFECT OF SALTS ON STRAWBERRIES (PERCENTAGE DIFFERENCES FROM CHECK)

Year		Yield per Acre			Area Leaflets	Weight Leaves	Petiole Length	
		1935	1937	1938	1937	1938	1937	1938
Cation	Anion							
Na	NO <sub>3</sub>	-26*	-31*	-38*	-45*	1	-35*	13*
	PO <sub>4</sub>	-32*	-27*	-5	-50*	-4	-31*	2
	SO <sub>4</sub>	-23*	-18*	-9*	-42*	-14*	-28*	-11*
NH <sub>4</sub>	NO <sub>3</sub>	-2	-2	-35*	6	25*	3	31*
	PO <sub>4</sub>	2	10*	-36*	18*	33*	9*	38*
	SO <sub>4</sub>	-4	8	-50*	5	26*	1	30*
Ca	NO <sub>3</sub>	-17*	1	-33*	11	11*	0	21*
	PO <sub>4</sub>	-9	11*	-8	1	0	1	3
	SO <sub>4</sub>	-3	5	-2	6	-3	1	-3
Significant differences.		15	10	9	15	8	6	8

\*Significant differences from check.

Reduction from check plots is indicated by minus (-).

sodium nitrate greatly reduced the yield, the leaf weight was the same as in the check plots.

The depression in yield caused by sodium sulphate was accompanied by a *decreased* leaf area and shortened petioles. An increase in petiole length of 30 to 38 per cent occurred in 1938 with ammonium salts and a decrease with sodium sulphate accompanied by decreased yield.

With sodium nitrate and calcium nitrate, there was an increase in petiole length accompanied by a significant decrease in yield. The ammonium salts, however, caused greater increase in petiole length than did nitrates minus ammonia, in spite of the fact that equal reduction in yield occurred with both nitrate and ammonium salts. Ammono-phos caused a greater increase in leaf weight and petiole length than the other nitrogen salts used. The yield, however, was not different from that obtained with other salts containing nitrogen except ammonium sulphate.

### DISCUSSION

In general there were marked differences in the effects of certain salts applied in the field on Howard 17 strawberries. Not only were different effects found with the application of certain salts but different effects were sometimes obtained between fall and spring application of the same salts. Sodium salts in the quantities used were highly injurious with respect to yield, leaf size and petiole length in fall applications, indicating a general and permanent dwarfing of the plant. Leaves and petiole measurements were made of the new growth of spring of the fruiting year in all the tests. Yield was also decreased with calcium nitrate applied in the fall of 1934, but not in 1936. Fall application of ammo-phos and superphosphate caused a small increase in yield over the check plots in 1937 but not in 1935.

When fertilizer application was delayed until spring of the fruiting year, sodium did not seem as toxic as in fall application. This was indicated by the fact that yield was reduced only 9 per cent and leaf weight and petiole length 14 and 11 per cent respectively with the use of sodium while sodium phosphate was not definitely injurious. In 1938, following fertilizer application in spring just before bloom, nitrogen caused adverse effects in all ammonium salt applications. A greatly reduced yield occurred on account of increased foliage development evidenced by larger and greener leaves as well as longer petioles. Yield was reduced equally as much with sodium nitrate as with calcium nitrate although increased vigor of plants was not so evident.

The results obtained in these experiments seem to point to the fact that sodium salts, in the amounts used and under soil and climatic conditions prevailing with these tests, hinder the development of strawberry plants doubtless because of toxicity to newly forming roots and accumulation in the plants. However, the leaf scorch described by Hoagland and Snyder (2) as the result of culture solution experiments with strawberries did not occur in the New Hampshire tests. That the concentration alone of sodium salts was not the causative factor is indicated by the fact that other salts in even greater concentration caused no apparent injury when applied in the fall.

With plants treated to these chemicals after root systems had been developed (spring applications of second year) sodium seemed only slightly toxic at the most.

Large amounts of nitrogen (not associated with sodium) did not increase the apparent vigor of strawberry plants taking root shortly after fertilizer application except possibly with Ammo-phos. When applied to plants previous to bloom, however, vegetative response was striking especially with ammonium salts. Undoubtedly the roots were then able to take up large amounts of the nitrogen before soil leaching could take place. Probably the less striking vegetative growth following sodium and calcium nitrate application was due to greater loss of nitrogen in this form before the roots could take it up.

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# Prevalence of Certain Diseases Affecting the Foliage in Some Strawberry Progenies<sup>1 2</sup>

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**I**NFORMATION on the ability of strawberry varieties to transmit resistance to scorch, mildew, and June yellows, which might permit breeders to plan their crosses so as to have a minimum of susceptible seedlings, would be extremely valuable. Although new varieties are frequently used for breeding purposes, where definite lines of breeding are being followed, it should be possible to build up a supply of facts about resistance which could be used to advantage. Accordingly, certain data secured in connection with the strawberry breeding project at the New Jersey Station have been summarized and are presented in this paper.

## LEAF SCORCH

Leaf scorch (*Diplocarpon earliana*) does not usually cause serious losses in New Jersey but some years it is prevalent enough to weaken a large proportion of the plants of certain varieties. In 1937 it was especially bad in the seedling blocks at New Brunswick. During the picking season of 1937, therefore, 2,623 seedlings were classified with respect to scorch as having none, or a slight, medium, heavy, or very heavy infestation. At this time each seedling consisted of a block of plants about 2 by 3 feet in extent, each block being a separate clone. Records were secured on 26 progenies resulting from self- or cross-pollination, 19 of which included 50 or more seedlings. Progenies including less than 50 seedlings are not included in this discussion.

Every one of the 19 progenies contained some seedlings showing no scorch, some showing slight and some showing heavy infestation. All but four included seedlings that were heavily infested. Only a very few seedlings were rated as very bad. Under different environmental conditions the number of scorch lesions on susceptible varieties might be greater or less. The number of seedlings entirely free from scorch lesions, therefore, is probably more significant than the number falling in the slight, medium, heavy or very heavy classes.

The data show that scorch was much more prevalent in seedlings from certain crosses and justify the conclusion that varieties vary in their ability to transmit resistance to that disease. Drain and Fister (6) also found considerable variation in the amount of scorch present on seedlings of different crosses although they worked with an entirely different group of varieties as parents.

The seedlings entirely free from scorch varied from 28.8 per cent in the cross New Jersey 303 x New Jersey 327 to 2.1 per cent in the cross New Jersey 430 x New Jersey 141. New Jersey 327 (Teddy Roosevelt x Pearl), to a greater extent than any of the other 14 varie-

<sup>1</sup>Journal Series paper of the New Jersey Agricultural Experiment Station.

<sup>2</sup>The assistance of the Works Progress Administration in certain phases of the work is acknowledged.

ties used as parents, was associated with a comparatively high percentage of seedlings free from scorch. Six out of the nine progenies which had more than 15 per cent of seedlings free from scorch had New Jersey 327 as one parent, whereas only one out of the ten progenies which had less than 15 per cent of seedlings free from scorch had New Jersey 327 as one parent. New Jersey 430 x New Jersey 141 not only gave very few seedlings free from scorch but when either of these selections was crossed with other varieties there was a very low percentage of scorch-free seedlings. The other varieties used as parents did not consistently produce seedlings either distinctly resistant or susceptible.

An analysis of the parentage of these crosses indicates that there was usually a low percentage of seedlings free from scorch when either Aberdeen, Chesapeake, or 10A (a selection of *Fragaria chiloensis*) appeared in the ancestry. However, when varieties with Aberdeen in the ancestry were crossed with New Jersey 327 there was a comparatively high percentage of seedlings free from scorch. The only variety in the ancestry of these progenies rather consistently associated with resistance to scorch was Teddy Roosevelt. Fairfax, Pearl and Wyona appear in the ancestry of both relatively resistant and relatively susceptible progenies and from these data might be classified as intermediate in their ability to transmit resistance. The data do not indicate that resistance to scorch is governed by a single gene but rather that some interaction of factors is probably responsible.

#### MILDEW

Each year mildew (*Sphaerotheca humuli*) has occurred on some of the strawberry varieties and seedlings being grown at the New Jersey Station in connection with the breeding project. The injury has usually been slight but it has been the policy to discard seedlings showing even a few infected leaves as they might be more severely injured if grown under conditions favorable to the rapid development of the disease. It has been noted that certain progenies were injured by mildew more than others, but extensive individual records were not taken until the fall of 1937. At that time 2,860 seedlings were examined and those showing more than a trace of mildew were so recorded.

A careful analysis of the data does not indicate that any one of the 19 different varieties, known to appear in the ancestry of the parents of these seedlings, is more closely associated with resistance than are the others. Aberdeen, Fairfax, Howard 17, Mastodon, and Pearl, for example, appear in the ancestry of certain progenies showing high and other progenies showing a low percentage of affected plants.

There was, however, great variation in the number of seedlings showing mildew in the different progenies. Seven out of the 37 progenies contained no seedlings with more than a trace of mildew. The seedlings of all five of the different crosses in which New Jersey 520 appeared as one parent were only slightly affected by mildew, less than 5 per cent in each case. On the other hand, New Jersey 521, a full sister of New Jersey 520, seemed to transmit susceptibility to the disease. The cross Wayzata x New Jersey 521 gave the highest per-

centage of seedlings affected by mildew or 78.1 per cent. Redheart, Aberdeen, Mastodon and Howard 17 are included in the ancestry of both New Jersey 521 and New Jersey 520. New Jersey 314 (Pearl x Fairfax) x New Jersey 352 (U. S. D. A. 854 x Fairfax) gave the second most susceptible progeny with 62.8 per cent of the seedlings affected. Judging from the data available the following varieties or selections, in addition to New Jersey 520, might be of value as parents in breeding for resistance to mildew; New Jersey 444 and 445, both second generation selfed seedlings of Aberdeen; New Jersey 388 and 390, both crosses between Fairfax and 10A, a *Fragaria chiloensis* selection; New Jersey 303; and possibly Catskill. The data indicate that resistance to mildew can probably be attributed to the action of more than one gene.

### JUNE YELLOWS

The condition variously known as June yellows, leaf variegation, yellow leaf, gold leaf, suspected mosaic, and non-infectious chlorosis is now quite generally accepted as being non-infective and genetic in origin (4, 5). If this is true then the appearance of a variegated (commonly known as "yellow") plant among normal green plants of any variety would presumably constitute a somatic mutation. In some varieties such as Blakemore, where selected green plants usually turn yellow eventually, there is what might be termed continuous mutating or an ever-sporting condition. Occasionally normal green varieties will produce yellow seedlings, presumably mutations.

One of the principal differences between this and the usual types of mutations is that a variety may appear to be normal green for some years and then plants in various localities begin the ever-sporting habit at about the same time. Within such a variety, selection of green plants which will continue to produce only green runner plants appears to be very difficult, if not impossible, although in the case of Blakemore some stocks have been found which produce very few yellow plants. June yellows constitutes a real problem for plant breeders as it may suddenly develop in all the stock of a promising selection which may possibly have been tested for several years or even named and introduced. Certainly all available information on June yellows should be made available so that breeders may avoid the waste of time and effort caused whenever it appears. Such information should include the rate of appearance of yellows seedlings in crosses of supposedly normal green varieties as well as the genetic behavior of the character in stocks known to carry it. A valuable contribution has already been made by Demaree and Darrow (5) who reported the occurrence of yellows in several selfed lines.

Records of the occurrence of seedlings showing the yellow character have been kept at the New Jersey Station since 1930. Table I shows the number of yellow seedlings occurring each year in progenies in which the yellow character was unknown in the ancestry.

In 1933, 29 of the yellow seedlings appeared in one cross, and in 1938 there was a total of 46 in two crosses between Green Mountain and two New Jersey selections. If these three crosses were omitted

TABLE I—NUMBER OF YELLOW SEEDLINGS OCCURRING IN CROSSES BETWEEN SUPPOSEDLY NORMAL GREEN VARIETIES

Year	Total Number of Seedlings	Number of Crosses	Number of Crosses Giving 1 or More Yellow Seedlings	Total Number of Yellow Seedlings
1930	1,617	13	0	0
1931	1,494	46	0	0
1932	721	25	4	6
1933	2,689	47	8	38
1934	1,005	24	2	2
1935	2,311	17	1	4
1936	1,470	28	2	2
1937	2,623	27	0	0
1938	2,781	37	4	49
Total . . .	16,711	264	21	101

from the table there would be 26 yellow seedlings in a total of 16,415.

Since there were so many yellow seedlings in these three progenies, the question arises as to whether one of the parents may not have been potentially yellow, and if so whether or not that variety, although green when the cross was made, might not turn yellow at a later date. The cross giving the 29 yellow seedlings in 1933 was 10A x New Jersey 51. 10A, a selection of *Fragaria chiloensis*, was used in several crosses but this was the only cross giving yellow seedlings. New Jersey 51 (Pearl x Aberdeen) remained green up to the time it was discarded in 1933.

The two crosses which produced a large number of yellow plants in 1938 were Green Mountain x New Jersey 520, which gave 33 yellow plants out of a total of 140, and Green Mountain x New Jersey 521, which gave 13 yellow plants out of a total of 84. Both New Jersey 520 and 521 include in their ancestry Redheart, Howard 17, Mastodon, and Aberdeen. New Jersey 520 and 521 were used in crosses with other varieties and no yellow seedlings were produced in a total of 470. When New Jersey 520 was crossed with New Jersey 521, however, there were two yellow seedlings out of a total of 83. The presence of these two yellow seedlings may or may not be significant. The data might be interpreted to indicate that Green Mountain carries the factor for yellow although, so far as the writer knows, yellow plants have not been observed in this variety.

Since 14 of the 21 progenies, listed in Table I as including at least one yellow seedling, have Howard 17 somewhere in their ancestry, it might be assumed that that variety was responsible for the yellow seedlings. Guba (7) has indicated that seedlings of Howard 17 include a large percentage of yellow individuals. Such an assumption is hardly justified in this case, however, as no yellow plants have appeared in the Howard 17 variety at New Brunswick and none appeared in 16 selfed seedlings of Howard 17. This may indicate that the Howard 17 used in the breeding work in New Jersey is genetically different from the Howard 17 frequently reported to be yellow in New England.

The fact that a considerable proportion of the seedlings of yellow varieties will be yellow was reported by Clark (2, 3), Berkeley (1), Plakidas (8), and Guba (7). Guba reported that the yellow condition was apparent in the young seedlings as soon as they came up, but

Plakidas found that it did not show up until the seedlings were a year old. The experience in New Jersey has been that the time of appearance of the yellows character may be in the seedling stage or a year or more later. Of the 49 yellow seedlings listed in Table I as having been observed in the fruiting season of 1938, only 18 were evident in the fall of 1937, although by that time each seedling had grown into a block of several full grown plants. Furthermore a progeny of 80 seedlings of New Jersey 526 x New Jersey 521 showed no yellow seedlings in the fall of 1937 but 29 were apparent by the time the fruit was ripe in 1938. This cross was not included in Table I as New Jersey 526 turned yellow soon after the cross was made and Table I includes only seedlings of supposedly normal green varieties.

In the spring of 1929 a few open pollinated seeds of Van Dyke, a yellow variety, were planted. Several of the seedlings were yellow, indicating, probably for the first time, that the yellow character is inheritable. Two of these Van Dyke seedlings were selected for further breeding, one which may be called Y being definitely yellow and one that may be called G apparently being a normal green. Aberdeen, a normal green variety used in crosses with these selections is designated as A in Table II. Crosses were made in the spring of 1931, and the seedlings planted in the field in 1932. Counts were made in the field during the picking season of 1933. Table II gives the results of these crosses.

TABLE II—RESULTS OF SELF- AND CROSS-POLLINATIONS OF GREEN AND YELLOW SELECTIONS

Cross	Total Number Seedlings	Number Yellow	Number Green
Y x Self	25	25	0
G x Self	132	32	100
Y x A	84	11	73
A x Y	96	10	86
G x Y	118	63	55
A x G	68	1	67

It is evident from Table II that the green selection, designated G, was able to transmit the yellow character although it did not itself show it. Selection G was not propagated further so it is not known whether it would have turned yellow at a later date. However, selection G when selfed or crossed with Aberdeen did not give as many yellow seedlings as did selection Y. Later a green selection from the A x Y cross was selfed giving 56 seedlings, all of which remained green for 2 years, after which they were discarded.

The data presented indicate that the yellow character is inheritable, that a potentially yellow variety may remain green for 2 years or more (hence ratios secured from young seedlings would not be significant), that one green selection from yellow parentage transmitted the yellow character but to a less extent than did a yellow selection, that another green selection when selfed gave only green seedlings and that a wide variety of crosses of apparently normal green varieties may produce an occasional yellow seedling. The evidence presented here would tend to agree with the suggestion of Demaree and Darrow (5) that the

yellow character is not due to a single gene. More extensive data will be necessary to prove whether complementary genes or some other form of factor interaction are involved.

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## Root and Crown Development of Strawberries<sup>1,2</sup>

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**E**ARLIER work from this station (1, 2) on strawberry runner plant thinning or plant spacing indicated, through differential yields and growth responses, a need for the study under field conditions of the seasonal development of runner-plant roots and other plant parts, especially in relation to plant thinning and late summer or fall application of fertilizers. In view of emphasis on fruitfulness of early formed runner plants, the seasonal development of such plants under spaced and matted rows was of especial interest.

This particular study was carried on during the season of 1937 under favorable growing conditions with frequent rains which provided ample moisture without excess. Plants of the Blakemore variety were set in March 1937 on a level Sassafra sandy loam soil at Salisbury, Maryland. With plants set 3½ feet apart in the row and rows separated by the same distance, the plot area consisted of nine rows, each 300 feet long.

Runner plant formation started late in June. On July 5 and 6 selection was made, and markers set for 1,000 runner plants which had just rooted and which were in the number two position from the mother plant in the runner series. Individual plant studies were made during the season from this selection of runner-plants.

Each of the nine plot rows received different treatment as to plant thinning and late summer fertilizer, as follows:

*Row 1.* Matted row, 24 inches wide, no fertilizer treatment or plant thinning.

*Row 2.* Limited to 12 plants per mother plant, using plants 1 and 2 of six runner series, thus placing three runners in each direction of the row from the mother plant to form a 24-inch width of row. Excess runners were removed weekly. No fertilizer treatment.

*Row 3.* Limited to 20 plants per mother plant using plants 1 and 2 of ten runner series, thus placing five runners in each direction of the row from the mother plant to form a 24-inch width of row. Excess runners removed weekly. No fertilizer treatment.

*Row 4.* Matted row as in row 1; plus fertilizer application August 12, as a top-dressing of a 6-6-5 fertilizer at rate of 800 pounds per acre.

*Row 5.* Limited to 12 plants per mother plant as in row 2; plus 6-6-5 fertilizer, August 12.

*Row 6.* Limited to 20 plants per mother plant as in row 3; plus 6-6-5 fertilizer, August 12.

*Row 7.* Matted row as in row 1; plus fertilizer application September 11 as a top-dressing of 6-6-5 at rate of 800 pounds per acre.

*Row 8.* Limited to 12 plants per mother plant as in row 2; plus fertilizer, September 11.

<sup>1</sup>Summer field work was done in 1937 by W. L. Bartholdi.

<sup>2</sup>Scientific Contribution No. 491, Dept. of Horticulture, Maryland Agricultural Experiment Station.

Row 9. Limited to 20 plants per mother plant as in row 3; plus fertilizer, September. 11.

Cultivating operations, like those commercially practiced, were the same for all the rows throughout the season.

Data on runner plant development were obtained from runner-plants (July 5 selection) at approximately weekly intervals during the summer. At each sampling date 10 random plants from each of the three thinning treatments were carefully removed from the plant bed by means of a metal cylinder, 10 inches in diameter driven 12 inches into the soil, which assured the lifting of the entire root system intact. Soil was removed from the root system with water from a garden hose, applied at low pressure to the block of soil. Plants then were separated into leaf, crown (stem) and root portions. Of various measurements taken on the fresh material, only greatest length of the roots are presented in this paper. Plant parts were dried in an electric oven at 80 degrees C to kill tissue and then stored before final drying to obtain dry weights. Dry weights of roots and crowns are presented here.

Following the weekly measurements during the period of July 14 to September 24, further sampling of runner plants on October 6, 1937 and March 17, 1938 was done by careful digging of 10 to 25 staked plants in each row. Practically all of the root system was obtained from

this sandy soil by this digging method.

#### RESULTS

In Fig. 1 plotted averages of plants from each of the plant thinning treatments show seasonal development in length and dry weight of roots and dry weight of crowns for the period approximately from the initial striking of runners through the initiation of flower buds, July 14 to October 6. Growth of plants had not ceased October 6 and continued until freezing weather in November, as indicated by the considerable increase in crown and lesser increase in roots shown in Table I.

The curves for dry weights of roots and crowns were smoothed by making sliding averages from the data calculating for each date, the

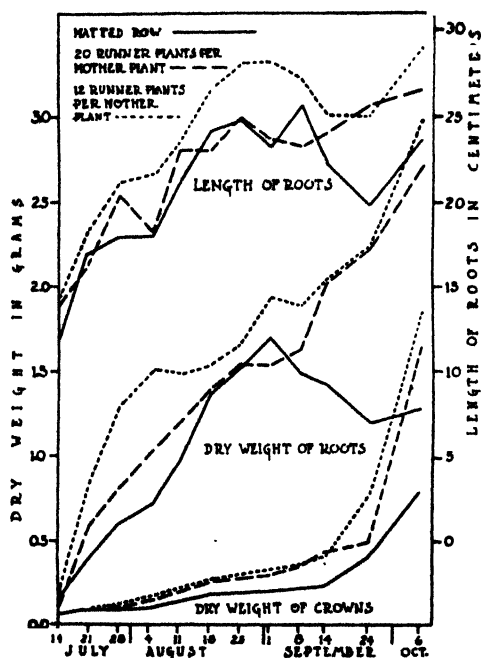


FIG. 1. Seasonal development of roots and crowns of Blakemore runner plants, showing comparisons of plants from matted-rows and thinned rows (matted rows averaged 112 plants per mother plant)



TABLE I—DRY WEIGHTS OF CROWN AND ROOTS OF BLAKEMORE STRAWBERRY RUNNER PLANTS AS INFLUENCED BY PLANT THINNING AND LATE SEASON FERTILIZER APPLICATIONS (DRY WEIGHTS IN GRAMS)

Row	Plant Thinning	Fertilizer Treatment†	CROWNS				ROOTS			
			Average Dry Weight Per Plant			Dry Weight Increase	Average Dry Weight Per Plant			Dry Weight Increase
			August 11 1937	October 6 1937	March 17 1938		August 11 1937	October 6 1937	March 17 1938	
1 4 7	Matted	None August 12, 1937 September 11, 1937	0.15 0.15 0.15	0.63 ± .03 0.83 ± .04 0.79 ± .03	1.05 1.53 1.62	August 11 1937 to October 6 1937	0.69 0.69 0.69	0.97 ± .06 1.46 ± .09 1.44 ± .10	1.16 1.74 1.62	August 11 1937 to October 6 1937
	Row	Average	0.15	0.75	1.40	0.60	0.69	1.29	1.51	0.60
3 6 9	20 RP/MP*	None August 12, 1937 September 11, 1937	0.22 0.22 0.22	1.38 ± .07 1.72 ± .10 1.52 ± .06	3.00 2.80 3.06	August 11 1937 to October 6 1937	0.95 0.96 0.96	1.82 ± .12 2.72 ± .21 2.63 ± .16	3.54 3.72 3.08	August 11 1937 to October 6 1937
	Row	Average	0.22	1.54	2.96	1.32	0.95	2.47	3.11	1.52
2 5 8	12 RP/MP	None August 12, 1937 September 11, 1937	0.21 0.21 0.21	1.56 ± .06 1.26 ± .08 1.58 ± .18	3.36 3.10 4.47	August 11 1937 to October 6 1937	1.34 1.34 1.34	2.46 ± .10 3.09 ± .28 3.20 ± .05	3.00 4.10 4.74	August 11 1937 to October 6 1937
	Row	Average	0.21	1.47	3.64	1.26	1.34	2.92	3.95	1.58

\*RP/MP = Runner plants per mother plant.

†Fertilizer treatment consists of a top-dressing of 6-6-5 at rate of 800 pounds per acre on the dates listed.

average of three dates, including the one preceding and the one following. Increase in dry weight of crowns was gradual until the middle of September, when a rapid increase was started. Before the end of July the plant thinning treatments resulted in a greater increase in dry weights of crowns compared with the matted row treatments, and thinning to 12 rp/mp<sup>3</sup> finally indicated clearly an advantage over the 20 rp/mp.

Dry weights of roots were greater throughout the season from plants thinned to 12 rp/mp than from 20 rp/mp or matted rows, and those from 20 rp/mp were greater at most sampling dates than from the matted rows. Similar relations are seen in length of roots. However, the most striking feature of root development is the cessation about September 1 of dry weight increase from matted rows compared with continued linear increase for plants from thinned rows. After October 6, some small increase in roots of matted row plants was noted as shown in Table I.

The cessation in development of roots in the matted row beginning about September 1 was probably associated with crowding of plants and a greater vegetative maturity of plants in this treatment, compared with the thinning treatments. Further evidence, not presented in this paper, of differences vegetatively between the thinning treatments was shown by number of leaves, green weight of leaves, and dry weight of leaves per plant. Plants from the thinning treatment of 12 rp/mp showed the highest degree of vegetativeness, while those from matted rows showed the least vegetativeness or a greater vegetative maturity, and the thinning treatment of 20 rp/mp occupied an intermediate position.

Table I presents dry weights of crowns and roots to show relations of plant thinning and late season fertilizer applications in which dry weight increases for two periods, August 11, 1937 to October 6, 1937 and October 6, 1937 to March 17, 1938 for both crowns and roots are shown. Comparisons of effects of fertilizer treatments applied August 12 and September 11 are thus presented more clearly, and in this discussion the two periods will be referred to as early and late respectively.

A definite response to fertilizer treatment regardless of time of application over the no fertilizer treatment is shown by the dry weight increase of crowns from the matted row in both early and late periods. Also, in the early period before October 6, fertilizer increased dry weight of roots for all plant bed treatments, compared with no fertilizer, with no indication of late effect except possibly with 12 rp/mp.

Accumulation of dry matter by the crowns and roots during the fall and winter months was evident regardless of plant thinning or fertilizer treatments, as shown by dry weight increase in each case, but greater increases resulted from plant thinning treatments than from matted row treatment. Also differences in favor of 12 rp/mp over 20 rp/mp were consistent for both crowns and roots. This accumulation of dry matter as shown by dry weight increase was greater in the crowns than in the roots. Comparing effects of fertilizer applied at the

<sup>3</sup>Runner plants per mother plant.

two different dates, there were no noteworthy differences in crown or root increases either in the early or late period following fertilizer applications.

As in previous work (2) plants from thinned rows developed much larger roots and crowns, compared with plants from usual matted rows, which in this experiment showed roughly a ratio of two to one in dry weight of crowns and roots in favor of the thinned treatments as shown by the averages in Table I. By calculation from row samples the matted rows had a plant population of 400,000 plants per acre, compared with approximately 71,000 plants per acre under the 20 rp/mp treatment and 43,000 for the 12 rp/mp treatment, which corresponds with similar plant populations in the spacing work reported in 1936, (2). In the removal of runners in the thinned rows, approximately 180,000 runners per acre were removed, principally in August and September. Thus considerably fewer runner plants actually were produced on thinned rows than on matted rows.

Summarizing, with both matted rows and thinned rows, early runner plants of Blakemore strawberry developed dry weight of roots at a rapid linear rate during the growing season, but plants from matted rows ceased this rapid development in early fall compared with continued development of thinned plants. Rapid crown development occurred in the fall after an earlier slow steady rate of dry matter increase. Fertilizers applied in mid-August or mid-September were effective in promoting increased dry matter of roots. The continued fall development of plants in thinned rows, as well as response to fall fertilizers, possibly has significance in the excellent fruiting behavior of such plants in the following spring compared with matted row plants.

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## Storage of Strawberry Plants

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THERE should be several advantages both to the nurseryman and to the grower in digging strawberry plants in the fall or early winter and holding them in storage for setting out in the spring. By this means the nurseryman could distribute the labor more evenly and have plants available for shipping over a longer period, and the grower might obtain plants that were less likely to have been winter-injured and that were dug at a time when the plants were in better condition for transplanting.

The winter storage of strawberry plants is a relatively new venture, and there are many phases of the problem about which further information is needed. The results of one season's investigations on certain phases of this problem have been sufficiently conclusive to justify a preliminary report.

Aamodt and Brierley (1) have reported on the experience of several nurserymen with the storage of strawberry plants under Minnesota conditions. They state that, "In all cases where the storage temperatures were above freezing, much trouble was experienced with growth of the crowns, mildew or storage rots, or drying". They report successful storage of plants in unheated sheds in which the temperature dropped to 15 degrees and 22 degrees F.

Hoffman and Evans (2) in New York obtained plants in the early spring from southern nurseries and held them at 31 degrees F for 2½ and nearly 7 weeks. The stored plants gave equally satisfactory results in the earlier planting and more satisfactory results in the later planting than plants freshly received from the nursery.

### MATERIAL AND METHODS

Howard 17 (*Premier*) strawberry plants were obtained from two nurseries located on the eastern shore of Maryland near Salisbury. The first plants were received on December 21, 1937, and from one of the nurseries at monthly intervals thereafter throughout the winter. Rather severe freezing weather for that section was experienced previous to the first digging, although the plants showed very little injury to the crowns.

Except as otherwise noted, the plants were stored in shipping crates with the roots packed in moist sphagnum moss in the center of the crates. Crates holding 600 and 1,000 plants were used. The storage rooms were held at constant temperatures with average fluctuations of about  $\pm 0.5$  degrees F.

Plants received from nursery A in December were stored both at 32 degrees F with high humidity and at 17 degrees F. Subsequent shipments from this nursery in January, February, and March were stored at 32 degrees with high humidity, and at 30 degrees with low humidity. At 30 degrees the plants were moistened at intervals to

prevent drying out. The water added froze around the roots but quickly dried from the exposed leaves. In order to retard transpiration from the plants, all of the leaves were trimmed from some of the lots received in December.

Howard 17 plants were received from nursery B only in December and were stored at 32 and 36 degrees F with both high and low humidity at each temperature. Plants of the Gem variety were also received from nursery B in December. These were divided into four lots as follows: (a) one lot was stored "in the rough" just as it came from the field in a bushel basket lined with moist burlap; (b) one lot was stored in the rough, as above, for 1 month and then washed, trimmed, bunched and packed in a crate for the balance of the storage period; (c) the third lot was packed and stored in a crate; (d) the fourth lot was treated the same as the third except that it was fumigated with methyl bromide when stored.<sup>1</sup> This treatment has been used for the control of Japanese beetles. Certain of the Howard 17 lots were also fumigated in this manner but just previous to planting. At the end of the storage period the plants were set out in the nurseries from which they were obtained. Plantings were made at monthly intervals, beginning with March 20 and 21 and extending in one instance to June 20. Freshly dug plants that had been left in the field over winter were set out as controls at the same times as the storage lots. As the blossoms developed they were removed from the plants to promote vegetative growth. At intervals during the growing season the percentage of plants surviving was determined and the vigor of their growth measured by counting the number of leaves and number of runner series per mother plant. Sproat, Darrow, and Beaumont (3) have shown that the possible crop of one season is determined by the leaf area developed the previous season.

#### PRESENTATION OF RESULTS

The relation of storage treatments to the growth of the plants is shown in Table I for nursery A and in Table II for nursery B.

*Comparison of Storage Plants with Freshly Dug Plants:*—The plantings made on March 21 and 22 were at about the height of the normal planting season for the eastern shore of Maryland. Under these favorable conditions an excellent stand was obtained with all lots except those from 17 degrees F storage. At nursery B (Table II) the storage lots regardless of storage temperature made consistently more growth than the control plants. At nursery A the plants stored at 30 and 32 degrees were equal to and in some instances superior to the controls.

With plantings of Howard 17 made in the latter parts of April and May under conditions less favorable for growth, the plants from storage made consistently and often markedly better growth than the controls, as indicated by leaf and runner counts and by percentage of

<sup>1</sup>The fumigation treatments were given by J. W. Bulger of the United States Bureau of Entomology and Plant Quarantine and consisted of an exposure of 4 hours at 60 degrees F to methyl bromide fumes at the rate of 3 pounds of methyl bromide per 1,000 cubic feet of enclosed space.

TABLE I—CONDITION OF HOWARD-17 STRAWBERRY PLANTS AFTER 2 TO 3 MONTHS' GROWTH IN THE FIELD FOLLOWING VARIOUS STORAGE TREATMENTS (NURSERY A)

Date Stored	Storage Temperature (Degrees F)	Plants Set Out March 22, 1938† Inspection June 23, 1938			Plants Set Out April 21, 1938 Inspection July 22, 1938			Plants Set Out May 20, 1938 Inspection July 22, 1938		
		Living Plants (Per Cent)	Leaves per Plant*	Runner Series per Plant*	Living Plants (Per Cent)	Leaves per Plant*	Runner Series per Plant*	Living Plants (Per Cent)	Leaves per Plant*	Runner Series per Plant*
Check. . . . .	Freshly dug**	96	6.0 ± 0.4	3.0 ± 0.3	67	2.8 ± 0.3	0.8 ± 0.3	90	3.4 ± 0.3	0.8 ± 0.2
December 21, 1937 . . . . .	32	96	6.8 ± .4	3.6 ± .4	—	—	—	71	2.4 ± 0.2	.3 ± .1
December 21, 1937 . . . . .	32**	94	6.5 ± .4	3.5 ± .5	100	6.2 ± .5	4.0 ± .5	99	6.6 ± .4	2.4 ± .3
December 21, 1937 . . . . .	17	11	4.3	0.0	99	7.0 ± .5	5.0 ± .3	100	5.9 ± .2	2.6 ± .3
December 21, 1937 . . . . .	17**	12	4.0	0.0	—	—	—	—	—	—
January 21, 1938 . . . . .	32	98	5.6 ± .4	2.2 ± .3	99	4.8 ± .4	2.6 ± .4	97	4.9 ± .4	1.2 ± .3
January 21, 1938 . . . . .	30	100	9.8 ± .5	6.9 ± .3	99	5.1 ± .3	3.3 ± .5	—	—	—
February 21, 1938 . . . . .	32	99	8.3 ± .4	4.6 ± .3	98	4.1 ± .4	1.6 ± .4	96	3.6 ± .6	.6
February 21, 1938 . . . . .	30	100	8.6 ± .4	6.0 ± .4	97	6.4 ± .5	4.4 ± .3	—	—	—
March 21, 1938 . . . . .	32	—	—	—	97	4.7 ± .3	3.3 ± .4	94	3.9 ± .3	.5 ± .2
March 21, 1938 . . . . .	30	—	—	—	99	5.0 ± .3	3.6 ± .3	—	—	—

\*Mean number with standard error.

\*\*Leaves trimmed off when stored or when set out in the case of freshly dug plants.

†Check plants set out earlier in the month under optimal planting conditions.

TABLE II—CONDITION OF STRAWBERRY PLANTS AFTER 2 TO 3 MONTHS' GROWTH IN THE FIELD FOLLOWING VARIOUS STORAGE TREATMENTS (NURSERY B)

Date Stored	Storage		Plants Set Out March 21, 1938 Inspection May 19, 1938			Plants Set Out April 22, 1938 Inspection June 22, 1938			Plants Set Out May 19, 1938 Inspection July 23, 1938		
	Temperature (Degrees F)	Humidity	Living Plants (Per Cent)	Leaves per Plant*	Runner Series per Plant*	Living Plants (Per Cent)	Leaves per Plant*	Runner Series per Plant*	Living Plants (Per Cent)	Leaves per Plant*	Runner Series per Plant*
<i>Howard-17</i>											
Check	Freshly dug		100	5.1 ± 0.2	0.7 ± 0.1	93	4.9 ± 0.2	1.5 ± 0.2	61	3.3 ± 0.3	0.4 ± 0.1
December 21, 1937	32	H	100	6.7 ± .2	1.0 ± .1	100	8.1 ± .3	2.2 ± .2	—	—	—
December 21, 1937	32	L	100	6.4 ± .2	1.4 ± .1	97	7.3 ± .3	2.2 ± .2	97	2.9 ± 0.1	0.0
December 21, 1937	36	H	100	6.4 ± .2	1.4 ± .1	98	7.3 ± .3	2.2 ± .2	—	—	—
December 21, 1937	36	L	98	6.3 ± .4	1.3 ± .1	99	7.3 ± .3	3.1 ± .2	—	—	—
December 21, 1937	32	L**	100	6.3 ± .4	1.5 ± .1	97	7.6 ± .3	3.0 ± .2	—	—	—
<i>Gem</i>											
Check	Freshly dug		—	—	—	100	4.2 ± .2	0.3 ± .1	—	—	—
December 23, 1937	32	H†	—	—	—	96	5.2 ± .2	1.3 ± .1	—	—	—
December 23, 1937	32	H†	—	—	—	97	4.7 ± .2	.9 ± .1	—	—	—
December 23, 1937	32	H‡	—	—	—	76	2.6 ± .1	.2 ± .1	—	—	—
December 23, 1937	32	H‡	—	—	—	53	3.2 ± .2	.3 ± .1	—	—	—

\*Number with standard error.

\*\*Fumigated with methyl bromide, 1 to 5 days before planting.

†Stored in rough until planted.

‡Stored in rough 1 month then washed, trimmed, and packed in crate until planted.

§Stored packed in crate.

¶Stored packed in crate. Fumigated with methyl bromide when stored.

stand. Plants of the Gem variety stored in the rough and set out in April also were superior to the controls, although the lot stored in a crate was not. This latter lot may have been dug a considerable time before storage which may account for the poor stand and growth obtained.

One storage lot was set out at nursery B as late as June 21. Even at this late planting a very good stand was obtained, and the plants had nearly as many leaves after 1 month of growth as were on freshly dug plants set out a month earlier. However, this late planting produced practically no runner plants by November.

*Comparison of Storage Temperatures:*—Some of the strawberry plants dug in December were stored at 17 degrees F. After 3 months storage at this temperature only 11 to 12 per cent of the plants lived (Table I), and these plants were stunted in growth. Obviously this temperature was too low for these plants, although Aamodt and Brierley (1) report successful storage of strawberry plants in sheds in which the temperature dropped at times to 15 and 22 degrees.

Plants from nursery A that were dug in December were stored at 32 degrees F; those dug in January and later were stored at 30 and 32 degrees. At 30 degrees there was a tendency for the plants to dry out and accordingly they were wetted at intervals. The added water froze in the sphagnum moss around the roots but soon evaporated from the exposed leaves. At the time of planting the leaves of plants stored at 30 degrees were withered and dry, and the plants did not appear as fresh as those stored at 32 degrees. However, an excellent stand was obtained in all instances with plants from either 30 or 32 degrees (Table I). Plants from 30 degrees in all instances produced more leaves and runner series than the corresponding lots from 32 degrees, and these differences are statistically significant for leaf counts in two of the five comparisons and for runner series counts in three of the five comparisons. The average of the five comparisons show 7.0 leaves per plant at 30 degrees and 5.5 at 32 degrees, and 4.8 runners per plant at 30 degrees and only 2.9 at 32 degrees.

Plants from nursery B were stored at 32 and 36 degrees F, with both high and low humidity at each temperature. An excellent stand was obtained with plants from both temperatures, and there was no consistent difference in the growth of comparable lots from the two temperatures. At the time of planting considerable browning of the leaves was noted in the plants from 36 degrees, and consequently they did not appear as salable as plants from 32 degrees. These results are contrary to experiences reported by Aamodt and Brierley (1), who state that in all cases where the storage temperatures were above freezing much trouble was experienced with growth of crowns, mildew or storage rots, or drying.

*Comparison of Humidities:*—At 32 degrees F the relative humidity averaged about 80 and 85 per cent respectively for the low and high humidity rooms. At 36 degrees the differences in humidity were greater, and the humidity averaged about 70 and 88 per cent respectively. The results (Table II) do not show any consistent or marked differences in the stand or growth of comparable plants from the high



and low humidities. Even under the low humidity at 36 degrees the sphagnum moss remained slightly moist until planting.

*Influence of Method of Packing:*—In general, the plants were trimmed, sorted, tied in bundles of 25 and packed with sphagnum moss in shipping crates holding 500 to 1,000 plants. The results indicate that this method of packing was entirely satisfactory for storage. Two lots from nursery B were packed "in the rough" in covered bushel baskets lined with moist burlap. These plants were not trimmed or sorted and had considerable soil adhering to them. After 1 month in storage one of these lots was washed, trimmed and packed in a shipping crate. The other was left "in the rough" until planted. The lot stored "in the rough" throughout appeared to be in excellent condition at the time of planting with the leaves still green and fresh, and, when planted, it produced slightly more leaves and runner series than the lot packed after only 1 month in the rough. Both lots were slightly superior to the control (freshly dug) plants as shown in Table II. By storing the plants "in the rough" it would be possible to dig a large number of plants during a relatively short period in the late fall and pack the plants whenever it was most convenient.

*Influence of Fumigation with Methyl Bromide:*—Fumigation with methyl bromide at the rate of 3 pounds of methyl bromide per 1,000 cubic feet of space at 60 degrees F for 4 hours has been used by the Bureau of Entomology and Plant Quarantine for the control of Japanese beetle infestations. If strawberry plants are to be stored, it is desirable to know whether this treatment can be applied to stored plants and whether it should be applied at the time the plants are stored or after removal from storage.

One lot of the Gem variety was fumigated at the time of storing. When planted the leaves and roots of this lot were brown and appeared to be dead. Only a 53 per cent stand was obtained with this lot compared with a 76 per cent stand for a comparably stored lot that was not fumigated (Table II).

Two lots of Howard 17 plants were fumigated just before they were set out, one in March and the other in April. Practically a perfect stand was obtained and there was no indication of injury or reduction in growth of these plants compared with comparably stored plants that were not fumigated (Table II). Blossom buds on the fumigated plants were also uninjured.

## DISCUSSION

These results indicate not only that it is possible to store strawberry plants for rather extended periods, but that under many conditions stored plants may be distinctly superior to freshly dug plants. By the use of cold storage the nurseryman may be able to more evenly distribute his labor, he may have plants available for both earlier and later markets, and, most important to the grower, he may be able to furnish superior plants that have not been winter-injured or that for other reasons are in better condition for transplanting.

At the present time growers generally demand freshly dug plants. Such plants would no doubt be superior to plants that have been

exposed to room temperatures for appreciable periods but might be distinctly less desirable than plants that have been under cold storage conditions. The leaves on plants from storage may appear to be more wilted and discolored than on freshly dug plants but the results of this year's trial indicate that such plants are in no way inferior and may be superior to freshly dug plants. It is not always possible therefore to judge the desirability of plants by their appearance.

Although these results show the feasibility of storing strawberry plants for as long as 6 months, they do not indicate at what time in the fall the plants first reach a condition suitable for storage. Further investigations are planned to determine this.

#### SUMMARY AND CONCLUSIONS

Strawberry plants, principally of the Howard 17 variety, from two nurseries were dug and stored in shipping crates at monthly intervals from December 21 to March 21 and set out in the field at monthly intervals from March 21 to June 21. Storage temperatures of 17, 30, 32, and 36 degrees F were used with high and low humidities at 32 and 36 degrees. Other treatments, as storing "in the rough", fumigating with methyl bromide, and removing the leaves, were applied to certain lots.

The growth of the plants from 30, 32, and 36 degrees storage was equal to and generally distinctly superior to that of freshly dug plants that were left in the field over winter. Practically all of the plants stored at 17 degrees F for 3 months were killed.

There was some evidence that plants stored at 30 degrees F produced more leaves and runners than those stored at 32 degrees. Plants stored at 32 degrees F grew as well as those stored at 36 degrees. On the basis of these results storage at 32 degrees F is recommended because of the superior appearance of the plants from this temperature as compared with those from 30 and 36 degrees. Storage humidity within the range tested was not an important factor. Plants stored at 32 degrees F for as long as 6 months grew satisfactorily. Under these conditions, the time of storage between December 21 and March 21 was not an important factor. Satisfactory stand and growth were obtained with storage plants set out as late as May 21, whereas the stand and growth of freshly dug plants were relatively poor by April 21.

Growth of plants stored "in the rough" for part or all of the storage period was slightly better than that of freshly dug plants. Removing the leaves from the plants at the time of storage was of no benefit. Fumigation of the plants with methyl bromide at the time of storage caused considerable injury, but fumigation just previous to planting was not injurious.

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# Phosphorus and Nitrogen Fertilization for Strawberries on Long Island, New York

By J. D. HARTMAN, *Purdue University, Lafayette Ind.*, and  
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STRAWBERRY culture is increasing as a commercial enterprise among vegetable growers on Long Island. The light, early, acid soils of this locality and its proximity to the New York City market make the industry a promising one, although it is as yet small.

From general information obtained from fertilizer experiments on crop plants in this section, the need for an adequate supply of nitrogen, phosphorus, and potassium is most apparent. Particularly is this true of nitrogen, which leaches very readily, and phosphorus, which is rendered unavailable by the active aluminum present at the low soil reactions encountered.

The general practice is to supply a side dressing of about 800 to 1,000 pounds of 4-8-6 fertilizer to the acre during the first year, after the plants have been set out for 4 to 6 weeks and are well started. In addition there is usually an August application of 250 pounds of nitrate of soda, and in some cases 250 pounds of 4-8-6 to the acre also. During the spring of the fruiting year a common practice among many growers has been to apply urea at the rate of about 50 pounds per acre. This latter treatment is claimed to increase yield and prolong vigor and consequent harvest period.

The experiments discussed in this paper were conducted at or near the Long Island Vegetable Research Farm to determine the following relationships: (a) The effect of urea applied in the spring of the fruiting year upon the yield and time of maturity of the Premier strawberry; and (b) The effect of nitrogen and phosphorus, applied during the year that the plants were set, on yield and time of maturity.

## METHODS AND RESULTS

For the first experiment Premier strawberry plants were planted in 3½-foot rows and spaced 22 inches apart in the row. The plants were set out April 15 and 16, 1934 and allowed to develop in matted rows.<sup>1</sup> The soil type for this experiment, as well as the others reported here, was Sassafras silt loam, the richest soil used for strawberries on Long Island. The usual local practice of applying 800 pounds of a 4-8-6 fertilizer as a side dressing in May, at the time of the first cultivation, was followed. In the fall of the same year 250 pounds of nitrate of soda and 250 pounds of 4-8-6 per acre were also applied as top dressings. During the winter of 1934-1935, the plants were plentifully mulched with salt hay.

<sup>1</sup>This experiment was located on a farm of H. R. Talmage and Son. The writers are indebted to these men for their cooperation.

On April 27, 1935 urea, at the rate of 52 pounds per acre, was applied broadcast over seven systematically distributed rows. An equal number of rows received no treatment. A summary of the data obtained is presented in Table I.

TABLE I—RELATIVE YIELDS OF STRAWBERRIES FERTILIZED OR NOT FERTILIZED WITH UREA IN THE SPRING OF THE FRUITING YEAR

Dates of Harvest	Urea (Quarts per Acre)	Nil (Quarts per Acre)	Difference Necessary for Significance* (Quarts per Acre)
June 7 to 14 inclusive.	946	1,283	—
June 7 to 28 inclusive.	9,260	11,466	224

\*The difference was shown to be significant by comparing the observed value of *z* with Fisher's values for *z* at the 5 per cent point.

For the second experiment the Premier variety was also used. This experiment was carried out in one location during 1935 and 1936 and repeated in another location during 1936 and 1937. The 1935–1936 crop was grown on a area which had in previous years been well fertilized, receiving 10 tons of manure per acre each year from 1922 to 1934, inclusive, as well as complete fertilizers approximating 2,000 pounds of 4–8–7 per acre per year. The 1936–1937 crop was grown on land of considerably lower fertility. It had received lesser amounts of commercial fertilizer during the preceding 15 years and no organic matter except that from crop residues and an annual winter cover of rye. The growth of vegetable crops on this land indicated that it had lower fertility than most other fields of Sassafras silt loam on the Island.

In both years rows were 3½ feet apart and plants set 18 inches apart in the rows. An individual replicate consisted of a single matted row 95 feet long in 1935–1936 and a single matted row 100 feet long in 1936–1937. There were four replicates of each treatment each year. Planting dates were April 4, 1935 and April 17, 1936.

The fertilizer treatments are listed in Table II. All phosphorus applications consisted of 20 per cent superphosphate applied broadcast at the rate of 100 pounds of  $P_2O_5$  per acre just before the plants were set. Nitrogen was applied to all plots, except those which received no fertilizer, at the rate of 53 pounds per acre in the year the plants were

TABLE II—YIELDS WITH FERTILIZER TREATMENTS APPLIED THE YEAR PLANTS WERE SET

Number	Treatment Description	1935–1936 Yields		1936–1937 Yields
		Early (Quarts per Acre)	Total (Quarts per Acre)	Total (Quarts per Acre)
1	Spring nitrogen.	2,581	5,620	7,099
2	Late summer nitrogen.	2,345	5,004	6,437
3	Spring and late summer nitrogen	2,489	5,292	8,707
4	Phosphorus and spring nitrogen	2,345	5,135	6,291
5	Phosphorus and late summer nitrogen.	2,279	5,030	6,996
6	Phosphorus plus nitrogen in spring and in late summer	2,437	5,489	7,006
7	Check	2,384	5,476	—

set. It was scattered in the form of sulfate of ammonia, closely around the plants. The descriptions in Table II indicate which treatments received all the nitrogen in the spring (April 25, 1935 or May 1, 1936), which received all the nitrogen in the late summer (August 26, 1935 or September 1, 1936), and which received half the nitrogen, 26.5 pounds, in the spring and half in the late summer.

The 1936-1937 crop was mulched with salt hay during the winter, but the 1935-1936 crop was not mulched at all. No fertilizers were applied during the fruiting season. Since the early part of the summer of 1936 was very dry, the experiment which was being picked at that time was irrigated during June. Harvesting in 1936 began on May 28 and ended on June 20. The corresponding dates for 1937 were June 7 and June 29. All berries picked before June 6 in 1936 were considered early.

None of the differences in yields between treatments, shown in Table II, are significant.

### DISCUSSION

The data given in Table I indicate clearly that fertilizing strawberries in the spring of the fruiting year was definitely disadvantageous. Yields were reduced by the treatment and this reduction was statistically significant.

None of the treatments applied in the year plants were set produced significant differences in yield. This result was not so surprising for the 1935-1936 experiment, conducted as it was on a soil relatively well fertilized in previous years. But vegetable crops grown on this land invariably responded to fertilizer. For example, celery in 1937 and celery, cauliflower and lettuce in 1938 grown on the identical piece of ground responded differentially to various fertilizer treatments. When, however, the 1936-1937 results are considered, there is definite evidence that strawberries under Long Island conditions require remarkably low levels of readily available nitrogen and phosphorus. The results of many workers would tend to indicate the sufficiency of a low level of soil nitrates for strawberries, but the fact that they did not respond to phosphorus on a soil where practically every commonly grown vegetable crop will respond is perhaps worthy of special mention. The average yield of all plots receiving phosphorus was actually lower than that for all plots receiving no phosphorus. Replicated fertilizer tests on Sassafras silt loam treated very much like the 1936-1937 test land had been treated showed, according to Wessels (1), the following optimum requirements for phosphoric acid ( $P_2O_5$ ) with various vegetables: potatoes, 120 pounds; tomatoes, 180 pounds; asparagus, 130 pounds; cauliflower, 170 pounds; lima beans, 150 pounds; spinach, 120 pounds; lettuce, 120 pounds; Brussels sprouts, 120 pounds; and peas, 150 pounds.

### CONCLUSIONS

Under Long Island conditions the Premier variety of strawberry did not benefit from applications of urea at the rate of 52 pounds per

acre made in the spring of the fruiting year. Yields were depressed by the application of nitrogen.

No significant differential response was obtained from varying the time of application of nitrogen to strawberries in the year the plants were set.

No significant response to phosphorus, broadcast before the plants were set, was found on a soil which requires large applications of superphosphate for maximum growth of many vegetable crops.

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# The Effect of Lime on the Low-Bush Blueberry

By F. B. CHANDLER, *Maine Agricultural Experiment Station,  
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IN 1931 lime was applied to blueberry land to study its effect on blueberry yields and soil pH. This paper presents the effect of lime applied once, twice or three times at the rates of 1, 2, 3, or 6 tons per acre per treatment. The original plan of the experiment was to study the effect of a single application, and therefore the second and third applications (1932 and 1934) were made on only part of the plots treated in 1931 and no replicate treatments were made. The plots were harvested in 1934 and again in 1936. Table I shows the percentage increase or decrease of the 1936 crop in relation to the 1934. Eleven of the 12 plots receiving lime had a larger crop in 1936 than in 1934 while only one of the three unlimed plots showed an increase.

Tons of Lime Per Acre Per Application	Number of Applications		
	One	Two	Three
None . . . . .	9.4 (Check)	-3.7 (Check)	-58.3 (Check)
1. . . . .	8.5	74.1	48.3
2 . . . . .	157.7	-12.6	34.2
3. . . . .	112.6	48.8	146.5
6. . . . .	103.6	112.6	272.9

These data show that lime increases the yield of blueberries and as much as 18 tons of lime per acre added in three applications was not detrimental. J. H. Clark of the New Jersey Agricultural Experiment Station has conducted investigations on the effect of lime as applied to high-bush blueberries and has obtained increases in yield from the lime (3). These results contradict a previous statement that lime or wood ashes were positively injurious to blueberries.

The study of the pH of soil samples taken at inch levels from the top 6 inches of soil of plots receiving 6 tons of lime per application, shows that the three applications have changed the pH through the top 6 inches of soil. These studies also show that the top inch is slightly alkaline, having a pH in some cases of 7.5. Composite samples of the top 6 inches show that the heaviest lime application (a total of 18 tons) has changed the pH only from about 5.0 to 6.6.

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# Influence of Certain Cultural Systems Upon Root Distribution of Black Raspberries

By LEON HAVIS, *Ohio Agricultural Experiment Station,  
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A BRIEF report of studies on the depth and distribution of roots of Logan black raspberry plants under mulch and cultivation treatments is given here. Beckenbach and Gourley (1) have described the distribution of roots of apple trees under mulch and cultivation in the same soil type. Colby (2) has described very briefly some observations on the rooting of certain raspberries under other but uniform soil conditions. The investigation reported here was made in order to correlate differences in growth and yield obtained under mulch and cultivation in this raspberry planting. Certain other studies made at this Station on the effects of straw mulch on the growth and production of this crop have already been reported (3).

## METHODS

The studies reported here were made during August and September of 1938 in a very uniform block of raspberries set out in the spring of 1931. The plants were set 2 feet apart in rows 9 feet apart. The mulch treatment described was begun in the fall of 1932 and enough wheat straw has been applied since then to keep the soil well covered, and to almost completely eliminate weed growth in both the rows and middles. An application of 3 to 4 tons of straw per acre annually was usually sufficient. The cultivation treatment has been continuous since the plants were set. The relatively large number of roots near the surface under this treatment indicates that many of them were not destroyed by cultivation.

In order to locate the roots in some detail, trenches were dug in two directions with respect to the rows of plants. The position which proved most satisfactory was at right angles to the row. By this plan a plant was first taken out and the trench dug 2 feet wide, thus about 1 foot from a plant on either side of the trench. This trench was 10 feet in length or 5 feet from the row in both directions and to a depth below all roots. The other position of trench used was located parallel to the rows, 7 feet in length, and about 2 feet from the plants. The side of the trench nearest the row was used in mapping the roots. In general, the results were similar to those secured with the other type.

Colored pencils were used to designate the various root diameters which were separated approximately into those 0 to  $\frac{1}{2}$  mm,  $\frac{1}{2}$  to 1 mm, 1 to 2 mm, 2 to 3 mm, 3 to 4 mm, and those over 4 mm in diameter. Those indicated as over 4 mm averaged about 5 mm in diameter. The roots were then mapped to scale and photographed. With the aid of representatives of the Agronomy Department of the Ohio Station, the principal changes in the soil profile were noted. Seven trenches were prepared and four of them were mapped on both sides,



thus a total of 11 charts were made. There was some difference due to variations in the soil profile, but, in general, the same variations between treatments obtained.

### RESULTS

The soil was classified as a shallow phase of the Wooster silt loam. It is well drained and is a good orchard soil. The 8 to 10 inches of surface is composed of a yellowish-brown silt loam soil. Below this there is a horizon which varies in thickness from 6 to 10 inches composed of a slightly heavier yellowish-brown silt loam that is lower in organic matter than the horizon above. Immediately below this, and extending to a depth of 24 to 30 inches is a horizon of rather compact yellowish-brown silt loam in which many pebbles of sandstone were found. At approximately 24 to 30 inches the glacial drift composed largely of sandstone was encountered. Where this was not extremely compact the raspberry roots grew for from several inches to as far as 2 feet into it depending on its compactness. No sharp change in root distribution due to change in soil profile was noted until the glacial drift was encountered. There was a fairly gradual decline in number of roots from a few inches below the surface to the drift of sandstone.

There was no significant difference in the depth of rooting under the mulch and under cultivation. Roots were usually found at a depth of between 4 and 5 feet under both treatments. The lateral distribution of the roots was also similar under the two treatments. The deepest roots were usually immediately below the plant. There was some tendency for fibrous roots to develop just under the mulch and in the mat of partly decomposed straw, but less so than is true of apple trees in the same soil type.

Roots were found near the surface under both treatments, but in the first foot of depth there were more roots under the cultivated treatment. This was true of roots of all sizes except those over 3 mm in diameter, and these represented only about 3 per cent of the roots under mulch and about 1 per cent of those under cultivation in the first foot of soil. About 90 per cent of the roots in the first foot under both treatments were less than 1 mm in diameter. Of the total number of roots of that size, approximately 42 per cent were in the first foot, 37 per cent in the second, 17 per cent in the third, 3 per cent in the fourth, and 1 per cent in the fifth foot of soil under both treatments. The distribution of the roots over 3 mm in diameter was somewhat different. Under the mulch there were about 70 per cent in the first foot, 25 per cent in the second, 5 per cent in the third, and none in the fourth and fifth foot. Under the cultivated treatment there were approximately 60 per cent in the first, 20 per cent in the second, 10 per cent in the third, 10 per cent in the fourth, and none in the fifth foot. The total number of roots over 3 mm in diameter was, however, greater in the mulch than in the cultivated treatment.

The total number of roots under the cultivation treatment was larger than under the mulch. In general, this was true of roots of all sizes except those over 3 mm in diameter. Actual counts of roots on probably the two most comparable profiles resulted in a total of 1,100

roots under mulch and 1,615 under cultivation. Counts of roots in all other trenches substantiated this result. Roots of the larger sizes were more numerous under the mulch and they were less branched and straighter. There was a decreasing gradient in number of roots of all sizes from the surface foot of soil downward, as well as from the base of the plant outward, although the latter trend was not so marked.

The roots were most numerous at 18 to 24 inches from the plant. The roots of the 8-year-old plants failed to extend well into the centers between the rows 9 feet apart. There was a gradual reduction in number of roots of all sizes as the distance from the plant was increased, and a sharp reduction at about 3 feet from it. This suggests that the rows could well be closer together than 9 feet if economy of space is an important factor. On soils similar to Wooster silt loam probably a distance of 6 feet would be more economical of space. In the placement of fertilizers under similar conditions, it would seem that along the sides of the rows and to a distance of 2 to 3 feet outward would be most economical.

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# Investigations on Mulching Red Raspberries

By GEORGE M. DARROW and J. R. MAGNESS, *U. S. Horticultural Station, Beltsville, Md.*

FOR several years attempts were made to grow raspberries at the United States Horticultural Station, Beltsville, Maryland, using standard cultivation practices. Growth of canes and productiveness were uniformly poor, notwithstanding adequate fertilization and, in most seasons, satisfactory moisture supply. This led to the establishment of experimental plots to compare permanent mulch, using straw as the mulching material, and cultivation.

Conditions at Beltsville are similar to those generally prevailing at the southern limits of raspberry growing. The growing season is long and relatively hot and humid. While cane growth was unsatisfactory, the poor condition could not be attributed to any known specific factor. The excellent results from mulching for the past 3 years seem to warrant a brief report at this time even though the details of the reasons for such differences in growth are not apparent.

The soil used for the tests is a Sassafras sandy loam which has especially good moisture conditions. In the spring of 1936 five 400-foot rows 7 feet 6 inches apart, were set with raspberry plants. Latham plants were set 2½ feet apart in two rows, and Cumberland 4 feet apart in two. One row of each variety was mulched with rye straw at the rate of about 8 tons per acre. One row of each was cultivated, the fifth row being used as a boundary between the mulched and cultivated areas. Some limiting factor, probably a virus disease, has prevented normal growth of the Cumberland and results with it are not discussed here. However, in growth and yield its response to mulching as compared to cultivation has been similar to that of the Latham.

Nitrate of soda equivalent to about 300 pounds per acre was applied about April 1 and again about July 1 of each year to both mulched and cultivated rows. Sufficient additional rye straw was applied to the mulched row in 1937 and 1938 to keep down all weed growth. The cultivated rows were disked in early spring, and lightly cultivated several times each season.

## CLIMATIC RECORDS

The moisture conditions were excellent most of the time and not particularly unfavorable during any part of the three seasons. At no time have the clean-cultivated plants appeared to be suffering from moisture deficiency. Temperature records at points 2 to 3 inches deep in the soil were taken with a soil thermograph from August 2, 1937 to July 20, 1938 in both the mulched and cultivated rows. The air temperatures are those in a thermograph shelter in the same field but about 600 feet distant. Graphs showing the weekly march of the maximum and minimum temperatures for this period are presented in Fig. 1. The average soil temperatures for the whole period were about the same

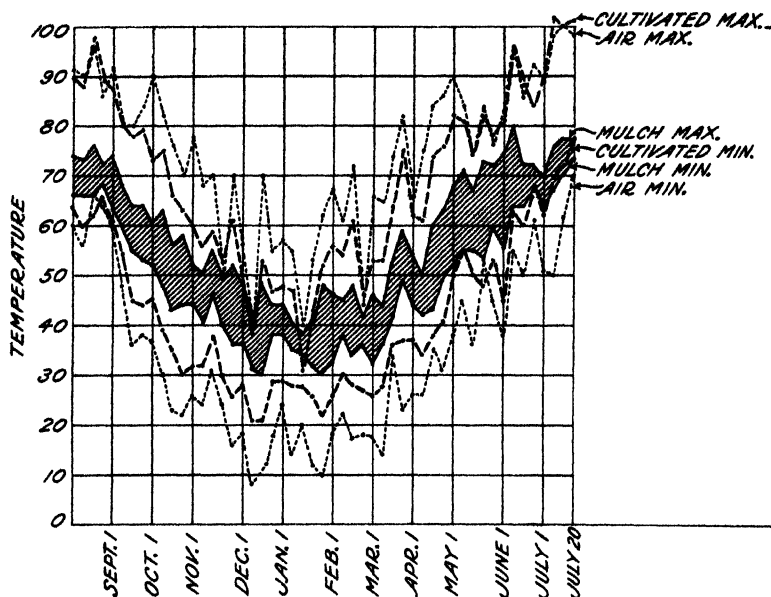


FIG. 1. Temperature graphs for Beltsville, Maryland, August 2, 1937, to July 20, 1938, showing maximum and minimum temperatures for each week 2 to 3 inches deep in soil in mulched and cultivated raspberries as compared to air temperature.

(52.7 degrees and 52.1 degrees F) in the two plots, but during the summer they were higher, and during the winter lower, under cultivation than under mulch.

The most notable difference in conditions between the mulched and the cultivated rows was in the day-to-day fluctuation of temperature (see Fig. 1). The mulch acted as an insulator and kept the soil temperature much more uniform than did the cultivation. The straw mulch was a better insulator during the fall and early winter (average weekly fluctuation August 2 to January 1 of 9.4 degrees F) than in mid and late winter and in spring (average weekly range February 1 to June 13 of 13.5 degrees) after it had become wet and packed. After additional mulch had been put on in June, 1938, it was again a good insulator (average weekly fluctuation June and July 7.0 degrees).

#### GROWTH AND YIELD RECORDS

Records were taken of the number of living plants, number of suckers removed, cane growth (of canes left) in total length, amount of fibrous roots, and production for the two rows. The amount of fibrous roots was obtained by taking, with a standard soil tube, soil cores 12 inches long and 1 inch in diameter. One hundred cores were taken 6 inches from the plants, and 100 at 12 inches from the plants. The roots were washed from these cores, the fibrous roots separated from larger root pieces, air dried and weighed.

As shown in Table I, the stand of plants (61 and 66 per cent) was not high at the end of the first season in either row. In October, 1938, after replanting twice, a 100 per cent stand of plants was alive in the mulched plot and but 70 per cent in the cultivated row. The total cane growth was about double in the mulched row as compared with the

TABLE I—GROWTH AND YIELD RECORDS FROM COMPARABLE 400-FOOT ROWS OF MULCHED AND CULTIVATED LATHAM RED RASPBERRIES AT BELTSVILLE, MARYLAND

	Mulched	Cultivated
Per cent of full stand:		
November, 1936	66	61
October, 1937	99	67
October, 1938	100	70
Total cane length (feet):		
November, 1936	982	491
October, 1937	6,721	1,229
October, 1938	8,155	1,998
Total	15,858	3,718
Number suckers removed:		
November, 1936	393	20
June, 1937	4,821	364
June, 1938	4,406	128
October, 1938	319	86
Total	9,939	598
Air dry weight of fibrous root; in 100 soil cores 12 inches deep:		
6 inches from crown (grams)	1.96	0.31
12 inches from crown (grams)	0.63	0.16
Yield (quarts):		
1937	13	3
1938	150	31

cultivated at the end of the first season, was over five times as great at the end of the second season, and was four times as great during the third year. The total number of suckers produced was about 16 times as great for the mulched as for the cultivated row for the three seasons. The fibrous roots were about five times as abundant near the mulched plants as near those under cultivation. The yield in 1938, the first full crop year, was five times as much from the mulched as from the cultivated row. The ratio of cane length of the mulched row to that of the cultivated in October, 1937, agreed fairly well with the ratio of fruit yield of the plots in 1938. Records of size of fruit were also taken at each picking in 1938, but no significant difference in this respect was found between the mulched and the cultivated plots.

The difference in plant survival, yield, cane length, and sucker production has been so large in this planting and the growth of the cultivated plants so poor, that there must be one or more limiting conditions effective in this field which are offset by the mulch. Soil erosion has not been serious in the cultivated row and would not account for the differences. The soil moisture conditions have apparently been good in the cultivated as well as the mulched.

The temperature differences between the mulched and cultivated soils have been great. The maximum of 102 degrees F noted in the cultivated soil is not high for roots of some crop plants, but might be for raspberries, which reach their best development under moderately cool summer conditions. The minimum temperature of 21 degrees must often be reached in the North by raspberry roots, and under

conditions there must not injure them, at least not seriously. Carrick's (1) studies do not indicate that a soil temperature of 21 degrees F would be injurious.

In view of the report by Wander and Gourley (5) indicating high availability of potash under straw mulch, analyses were made of leaves collected from the mulched and cultivated areas late in the fall of 1938.<sup>1</sup> Leaves from the cultivated plot contained 0.86 per cent potash on a dry weight basis, while the leaves from the mulched row analysed 2.39 per cent potash. This great difference in potash content of leaves suggests that potash availability may be one factor in the growth differences found although definite potash deficiency symptoms such as have been reported by Stene (4) in Rhode Island were not observed. Other nutrient materials, possibly some of the so-called "trace" elements, may also have leached from the mulch and become available to the raspberry plants.

It should be emphasized that the use of mulch has apparently corrected some conditions which prevents satisfactory growth of raspberries under the conditions of this experiment. Growth and fruiting under mulch were satisfactory but not superior to what is usually found under cultivation in good raspberry areas. Clark (2) in New Jersey and Havis (3) in Ohio have each reported increased growth and production from the use of mulch on raspberries, but to a much less extent than was obtained at Beltsville.

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<sup>1</sup>Analyses by Dr. J. G. Waugh.

## A Spectrographic Study of Concord and Ontario Grape Varieties

By C. A. MAGOON, A. T. MYERS, I. W. DIX, and B. C. BRUNSTETTER,  
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THE development of the spectrograph and of reliable methods for its use in quantitative chemical analyses has placed in the hands of biologists a valuable tool for use in the study of the inorganic constituents of plant and animal tissues, their influence on metabolic processes, and related problems. Spectrographic analyses have the advantage of rapidity and sensitivity and the results are preserved in permanent form as photographic records. A spectrogram obtained from a sample of plant ash consists of a series of black lines of greater or less density (slit images) on a photographic plate. The position of a particular line tells with certainty the element responsible for the radiated light of that particular wave length. The degree of blackness or density of the lines when compared with that of a series of lines from the same element obtained by burning off various dilutions of a stock standard solution containing this element permits a satisfactory quantitative determination of the element. Since as many as seven elements, in some cases, may be determined simultaneously in one region of the spectrum and others in other spectral regions the rapidity of the spectrographic method is obvious. It was used in the present instance to throw light on the problem of the mineral intake of grape vines as influenced by different cultural treatments and vineyard practices and to study varietal differences in grapes. This report, dealing with the Concord and Ontario varieties growing on their own roots, presents results on some phases of a broader study involving not only these varieties but also the Delaware, grown on 11 different rootstocks as well as on their own roots, in a grape rootstock test begun in 1933 at the United States Horticultural Station at Beltsville, Maryland.

The present data, dealing with leaf and node tissues of the Concord and Ontario varieties, show their content in potassium, magnesium, phosphorus, calcium, aluminum, iron, copper, manganese and boron, as determined by spectrographic analysis, for vines grown with cornstalk mulch versus clean cultivation, and with application of a 5-8-5 complete fertilizer, at the rate of  $\frac{3}{4}$  pound per vine, versus nitrate of soda, at the rate of 1 pound per vine. In the mulching experiments, cornstalks were applied in the fall of 1936 on each side of the rows to a width of 18 inches to 2 feet and to a depth of 6 to 8 inches, and the mulch was renewed the following fall. The fertilizer treatments were begun in the early spring of 1937 while vines were still dormant, and the treatment was repeated in the early spring of 1938. A plot sketch of the stock test vineyard (Fig. 1) shows the location of the varieties, the alternate arrangement of the clean-cultivated and mulched rows, the sections receiving the different fertilizer applications, and the position of the individual vines concerned in the present study. It is recognized that from the standpoint of the randomization of samples the use of vines here was not as satisfactory as might be desired, but





Leaf and flower cluster samples were taken about the first of May, prior to spraying, from the new shoots on pruned canes of these same vines, each sample being a composite of eight to ten leaves, 2 to 3 inches in diameter, and the same number of flower clusters. The flower buds were still closed at the time of sampling. The leaves and flower clusters were pinched from the shoots, using nickel-plated forceps, and transferred to new paper bags. When the sample was complete the mouth end of the bag was folded over and fastened with staples to prevent entrance of dust or other contamination. The bags were taken at once to the laboratory and placed in the drying oven maintained at 99 to 101 degrees C for 24 hours and then stored in a clean dry chamber until needed.

The samples were ground for analysis, using a Wiley mill of intermediate size, the exposed parts of which were nickel-plated, and the ground material was passed through a chromium-plated bronze screen of 40 mesh. The mill was carefully demounted and cleaned with a brush and compressed air between the grinding of individual samples so that there was no carry-over from sample to sample. The ground samples were placed directly into clean screw-top glass vials and before weighed portions were taken for analysis were dried at 100 degrees C in the oven and held in a desiccator until weighed.

Weighed portions of 10 or 20 milligrams as required, were taken, transferred directly to the crater of the electrode for ashing and the subsequent analytical processes carried out. Triplicate determinations were made from each vineyard sample.

The spectrograph instrument used was of the large Littrow type manufactured by one of the leading makers of optical equipment, and quantitative determination of the value of the spectral lines was made by use of a standard densitometer manufactured by the same company.

Details of the analytical procedures were the same as those described by Brunstetter, Myers, Wilkins and Hein (1) before the Sixth Spectroscopy Conference held at the Massachusetts Institute of Technology, July 1938, the proceedings of which are now in process of publication.

The data presented here involved the carrying through of 880 analyses in triplicate, or 2,640 separate determinations. All values are calculated on the basis of the dry weight of the samples.

Spectra of stock solutions of different dilutions prepared from purified chemicals containing the various elements under consideration were photographed on each plate to serve as standards of comparison.

Evidences of possible contamination were noted in only five cases.

In the comparison of the data from mulched versus clean-cultivated vines, from complete fertilizer versus nitrate of soda-treated vines, and Concord versus Ontario varieties with complete fertilizer and nitrate of soda applications, standard statistical methods have been employed and the significance of differences determined by application of Student's method as extended and adapted to this use by Fisher (2).

#### PRESENTATION OF DATA

Table I gives in the form of the usual statistical units the quantitative values for the different elements obtained in the analyses and furnishes

TABLE I.—SUMMARY OF SPECTROGRAPHIC DATA ON LEAVES AND NODES OF CONCORD AND ONTARIO GRAPES

Leaves						Nodes				
Element	Number of Vines	Mean (Per Cent)	Standard Deviation	Standard Error	Coefficient of Variance	Number of Vines	Mean (Per Cent)	Standard Deviation	Standard Error	Coefficient of Variance
Concord										
K	20	1.97	0.232	0.052	11.8	20	0.44	0.121	0.027	27.5
P	20	.61	.083	.018	13.6	20	.11	.022	.0049	20.0
Ca	20	.57	.122	.027	21.4	20	.48	.118	.026	24.6
Mg	20	.28	.042	.009	15.0	20	.12	.022	.005	18.3
Al	20	.045	.0084	.0018	18.7	20	.0008	.00033	.000074	41.2
Fe	20	.019	.0057	.0013	30.0	20	.0030	.00064	.00012	16.0
Cu*	20	41.0	4.0	.89	9.8	20	16.0	2.44	.545	15.2
Mn	20	.018	.0044	.0010	24.4	20	.0037	.00067	.00014	18.1
B*	20	17.0	4.85	1.08	28.5	20	4.8	.53	.12	11.0
Ontario										
K	18	2.20	0.409	0.096	18.6	18	0.42	0.118	0.028	28.1
P	18	.49	.085	.021	11.6	18	.11	.023	.005	20.9
Ca	18	.27	.064	.020	17.9	18	.47	.129	.030	27.4
Mg	18	.041	.0056	.0013	19.7	18	.04	.018	.004	19.4
Al	18	.022	.0091	.0021	41.4	18	.009	.0024	.0006	26.7
Fe	18	.022	.0091	.0021	41.4	18	.0028	.00042	.00009	15.0
Cu*	18	47.0	5.2	1.23	11.1	18	15.0	2.52	.6	16.8
Mn	18	.022	.004	.0009	18.2	18	.0046	.0016	.00037	24.8
B*	18	16.0	3.0	.72	18.8	18	4.8	.62	.15	12.9
Significance of Difference of Concord Versus Ontario Leaves										
Element	Difference of Means		S. E. of Difference		Diff./S. E. of Diff.		Remarks			
Mg	0.06		0.0108		5.56		Very significant			
P	.15		.0277		5.42					
Cu*	6.0		1.51		3.97		Significant			

\*Cu and B values expressed in parts per million.

TABLE II—SUMMARY OF SIGNIFICANT DIFFERENCES

Comparison	Treatment	Element	Concord Mean Per Cent	Ontario Mean Per Cent	Total Degree Freedom	Difference of Means	S. E. of Difference	Value of "t"	Remarks
Leaf Tissue									
Concord vs Ontario.	N-P-K	Mg	0.281	0.216	16	0.065	0.041	3.241	Very significant
Concord vs Ontario.	Nitrate	Mg	.275	.222	18	.053	.030	3.911	Very significant
Concord vs Ontario.	N-P-K	P	.552	.770	18	.218	.079	6.170	Very significant
Concord vs Ontario.	N-P-K	P	.657	.756	16	.099	.074	2.820	Significant
Concord vs Ontario.	N-P-K	Cu	40.7*	46.2*	16	5.5*	4.7*	2.479	Significant
Concord vs Ontario.	Nitrate	Cu	41.0*	47.0*	18	6.0*	5.2*	2.829	Significant
Concord vs Ontario.	Nitrate	Mn	.0169	.0214	18	.0045	.0028	3.594	Very significant
Concord vs Ontario.	N-P-K	Ca	.571	.444	16	.127	.10	2.658	Significant
Mulch vs Clean Cultivation									
Concord		Cu	43.0*	38.7*	18	4.3*	3.416*	2.813	Significant
Ontario.		Mg	0.239	0.204	16	0.035	0.017	4.29	Very significant
N-P-K vs Nitrate.									
Concord		P	657	.552	18	105	.06	3.738	Very significant
Ontario		B	14.4*	17.2*	16	2.8	2.75	2.185	Barely significant
Node Tissue									
Concord vs Ontario.	Nitrate	Mn	.0040	.0033	18	.0007	.000738	2.119	Barely significant

\*Values for copper and boron expressed in parts per million.

a basis of comparison of the over-all differences in the content of the nine elements studied in the leaves and nodes of the two varieties. The mineral content was much higher in the leaves than in nodal tissue for all the elements studied, except in the case of calcium where little difference is noted.

While significant differences are to be seen here in the mineral content of the two varieties, particularly with respect to magnesium, phosphorus and copper, the full measure of their significance is to be obtained best by a comparison of the analytical data so paired as to conform with the physical arrangement of the test vines under the different treatments. The same applies to the determination of the influence of cultural practices and fertilizer treatments on the mineral intake of the plants. Such comparisons have been made. In many cases where this has been done no significant differences have been found. For example, in none of the comparisons made, involving the cultural treatments, fertilizer applications and varietal differences studied, were significant differences found for potassium, iron or aluminum in either leaf or nodal tissues; none of the other elements, except copper in the case of Concord and magnesium in the case of Ontario, showed any influence of mulch versus clean cultivation; and the differential effects of complete fertilizer versus nitrate of soda applications were strikingly negative for most of the elements studied. In the case of those where significant differences have been found the evidence is presented in condensed form in Table II under the head of the usual statistical units.

#### DISCUSSION

The real meaning of the present findings cannot be assigned with certainty until more is known of the conditions which influence the intake of different mineral elements into the grape plant, which ones and in what amounts they must be present to assure the welfare of the plant, what effect each has on plant metabolism, and what interrelations of mineral elements are involved in plant behavior. It is unsafe to generalize from experimental data secured from one place only where but one particular set of conditions exist. Similar information from many sources is needed. One may be permitted, however, to comment briefly on some of the ideas suggested by the present findings.

It appears that there is no marked storage of mineral elements in the nodal tissues of grapes, these being brought into the growing parts of the plant from more remote sources, and the determination of varietal differences, therefore, could hardly be made by analysis of dormant tissues. The mineral content of nodal tissues of growing canes cannot be learned from the present data. The mineral content of young growing leaves appears to give a good index of the mineral nutrition of the plant but further studies are required to establish this point.

The importance of the differences noted in the magnesium, phosphorus and copper content of the Concord and Ontario varieties is not certain, but the magnesium would probably be concerned in the carbohydrate metabolism of the plant and may account for the apparently greater chlorophyll content of the leaves of the Concord as

compared with the Ontario variety. The significance of the higher content of phosphorus in the Ontario leaves is being considered with much interest.

It was somewhat surprising that greater differences were not found in the case of the mulched versus clean-cultivated vines, but this failure may have been due to insufficient decomposition of the mulch to be recorded in this fashion, although decomposition was well advanced. The object of its use was primarily to conserve moisture, and it may be that this will prove to be its most useful function.

Equally surprising were the findings as regards differences in fertilizer treatments. Since many unknown factors are operative in the soil the significance of these results must await further study.

It appears clear that the successful attack on plant physiological problems relating to culture, nutrition, and possibly also reproduction, may be materially and rapidly advanced by the application of spectrographic analytical methods.

### CONCLUSION

The present study on Concord and Ontario grape varieties by means of spectrographic chemical analyses of leaf and node tissues has shown significant differences in the mineral content, under the conditions of the present experiments, particularly with respect to magnesium, phosphorus and copper, in the case of young growing leaves. The Ontario was higher in phosphorus and copper while Concord was higher in magnesium. Nodal tissues did not show the same differences.

The mineral content of grape leaves was higher in magnesium, phosphorus, copper, potassium, manganese, aluminum, iron and boron than the nodes, while calcium was present in about equal amounts in the two types of tissues.

Only in the case of copper with the Concord variety and magnesium with the Ontario was any significant difference noted where mulched vines were compared with those having clean cultivation, the mulched vines showing greater amounts of these elements in the leaves.

In the case of comparison of the effect of complete versus nitrate of soda fertilizers on the mineral content, in only two cases was a significant difference found, namely, in the leaves of the Concord where a significantly greater amount of phosphorus was noted under complete fertilizer application, and in the leaves of the Ontario where barely significantly greater amounts of boron were noted from vines treated with nitrate of soda.

In only one instance was a significant difference found from comparison of the results obtained from nodal tissues, this case being a slightly greater amount of manganese in the nodes of the Concord variety from vines receiving an application of nitrate of soda.

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## Transpiration in Strawberries

By G. F. GRAY, *Oklahoma Agricultural and Mechanical College, Stillwater, Okla.*

THIS paper is a preliminary report on studies to determine the effect of environment (soil and air) upon transpiration and plant growth of different strawberry varieties. Variations in climatic adaptability have been observed in our variety trial plots, some varieties being much more susceptible to drought injury than others. Two varieties showing wide variation in drought-resistance, the Blakemore and Dorsett, were used for the tests reported in this paper. The Blakemore is quite drought-resistant, while the Dorsett suffers from severe burning of the foliage and loss of plants during July and August.

Two methods were used to measure transpiration rates (a) the potometer method using well-rooted runner plants and (b) plants growing in glazed pots sealed with paraffin.

### TRANSPIRATION MEASUREMENTS BY THE POTOMETER METHOD

The nature of the strawberry plant necessitated a change from the type of potometer used for measuring transpiration of excised shoots. Well rooted uniform runner plants were carefully dug and the soil washed from the roots. All old or injured and immature leaves were removed, leaving three fully developed leaves per plant. Then they were mounted in 500 cubic centimeter aspirator bottles. The purpose of using the entire plant was to avoid premature wilting of the leaves, as experienced by workers using excised leaves or twigs. It was possible to attach the burettes to the aspirator bottles direct and adjust the water level without disturbing the plant mounted in the stopper. Attempts to seal the crown of the plants in the stoppers were unsuccessful, therefore, the plants were mounted by enlarging one hole of a two-hole stopper, then slitting open the enlarged hole. The leaf petioles were inserted, suspending the crown and roots beneath the stopper, then cotton carefully packed around the petioles, the roots and crown placed in the bottle, and the petioles sealed in with a mixture of melted paraffin and vaseline (4-1) before forcing the stopper in place. As soon as the wax cooled, the other hole was plugged with a glass rod. The apparatus was set up in the greenhouse to eliminate the effect of excessive air currents, the greenhouse being well shaded with white-wash. The evaporating power of the air was measured by means of Livingston's atmometers. Readings of water loss, temperature and humidity were taken every hour. Plants for the test were grown in specially prepared beds of uniform soil, part of which was shaded with lath shades.

It was assumed that, since the entire plant was being used, each test could be extended over several days, however, the transpiration rate was slightly slower the second day and by noon of the third day, transpiration had practically stopped with some plants showing slight wilting. Therefore, only the results for the first 2 days of each test are reported. No readings were taken between 7 p.m. and 7 a.m. However, the seals were not broken and a reading of water loss for the 12-hour period was recorded.

Five plants from each lot were used for each test. Since the variation between plants was very slight, the average of the group is presented in Table I.

TABLE I—TRANSPIRATION OF 3-LEAF BLAKEMORE AND DORSETT STRAWBERRY PLANTS IN WATER IN THE GREENHOUSE (AVERAGE OF FIVE PLANTS)

Beginning of Test		10:00 A.M. August 1	12:00 M. September 7	12:00 M. October 1
End of Test		7:00 P.M. August 2	7:00 P.M. September 8	7:00 P.M. October 2
Variety	Treatment	(Cc/Sq In)*	(Cc/Sq In)	(Cc/Sq In)
Blakemore . . . . .	Grown in open	2.10	1.35	1.179
	Grown in shade	—	1.11	1.186
Dorsett . . . . .	Grown in open	2.58	2.30	1.183
	Grown in shade	—	1.58	1.150
Evaporating power of air by Livingston's atmometer . . . . .	—	54.80	56.87	55.37

\*Measured by the potometer method, recorded in Cc transpired per square inch of leaf area.

From the results secured in these preliminary tests, it appears that early in the season the Dorsett transpires more rapidly than the Blakemore. This difference, however, is not apparent as the plants become older, even though the evaporating power of the air during the test period was practically the same.

#### TESTS WITH POTTED PLANTS

Two soil types (a) sandy loam and (b) clay loam were used in this test. Each type was divided into three soil moisture levels, 40, 60, and 80 per cent of the water-holding capacity of the soil, designated in Table II as low, medium and high, respectively. Well-rooted young runner plants of uniform size were planted in pots, and grown until well established. Six uniform plants from each series were then selected and adjusted to four full developed leaves per plant, the old and young leaves being removed. The pots were then sealed and adjusted to the correct weight. The plants were weighed daily and brought up to standard by adding water from a burette, thus measuring the daily loss through transpiration. The test was continued from November 10, to December 3, 1938. The leaves were then removed for leaf area determination. Very rapid and accurate measurements were made with a planimeter by pressing the leaves in an herbarium press, then placing them beneath a sheet of thin wrapping paper fastened to a drawing board.

The results of this test as presented in Table II are quite contradictory to those secured by the potometer method early in the season.

The temperature range in the greenhouse during this period was from 65 to 75 degrees F and the average humidity higher than during the former periods. Under these conditions the Blakemore has shown a higher transpiration rate than the Dorsett, but variations in soil moisture have not materially affected transpiration rate.

No explanation can be offered at present for the reversal of behavior of the two varieties under the two methods of testing transpiration rate. The plants selected were of uniform size and age and there was

TABLE II—TRANSPIRATION OF BLAKEMORE AND DORSETT STRAWBERRIES  
GROWN IN SEALED POTS IN THE GREENHOUSE (NOVEMBER 10 TO  
DECEMBER 3)

Variety	Soil	Moisture Content	Leaf Area (Sq In)*	Transpiration (Cc)	Transpiration (Cc/Sq In)
Blakemore	Sandy loam	Low	89.62	1591.3	17.75
		Medium	91.88	1610.6	17.53
		High	73.68	1351.7	18.34
Dorsett	Sandy loam	Low	81.08	1241.7	15.31
		Medium	101.04	1373.0	13.59
		High	103.26	1451.8	14.06
Blakemore	Clay loam	Low	86.32	1270.0	14.71
		Medium	103.51	1459.0	14.09
		High	106.76	1713.3	16.05
Dorsett	Clay loam	Low	111.55	1316.3	11.80
		Medium	121.00	1444.9	11.94
		High	111.15	1394.6	12.56

\*Six plants, four leaves per plant.

but slight variation in the number of leaves removed from each plant.

The first two series of the first test (Table I) show that the Dorsett has a higher transpiration rate than the Blakemore, but the difference is only slight in the third series with plants grown in the open and reversed with plants grown under lath shade. The Blakemore also transpired more than the Dorsett in the second test (Table II). This apparent reduction in transpiration rate may explain why the Dorsett plants which survive the adverse climatic conditions during July and August make such remarkable recovery and produce a good crop of berries the following spring. However, the failure to produce a good stand of plants limits their use as a commercial variety in this section.

## Composition of Grape Leaves in Relation to Uneven Coloring of Concord Grapes

By JAMES E. WEBSTER and FRANK B. CROSS, *Oklahoma Agricultural and Mechanical College, Stillwater, Okla.*

### ABSTRACT

This material will be published as part of a bulletin from the Oklahoma Experiment Station.

CHEMICAL analyses have been made of the leaves from Concord, Worden, Moore Early, Ellen Scott, Campbell Early, Bailey, Extra, Sheridan, Fredonia, and Delaware varieties of grapes. Included in the analyses are results for solids, ash, various carbohydrate fractions, and total and soluble nitrogen. Such analyses were made on samples collected at intervals during the entire season. In mature leaves, solids and ash percentages increased continuously throughout the season. Carbohydrate fractions decreased irregularly until after harvest time when a general increase continuing until near frost was noted. Nitrogen percentages, while showing some fluctuations, remained surprisingly constant throughout the entire season. These results indicate that there is no unusual storage or fluctuation of such components in the leaves of the Sheridan and Concord plants whose fruits show such marked uneven coloring at harvest time in Oklahoma.



# Reducing Sugars in the Strawberry Plant

By J. H. LONG, *Christian College, Columbia, Mo.*

INASMUCH as the seasonal changes in the content of nitrogen, total sugars, starch, and hemicellulose in the strawberry have been reported (4), the object of this paper is to present data on reducing sugars. No attempt was made to identify these sugars. Materials were prepared according to methods already described (4). Chemical analyses were made by methods outlined by Murneek (5).

Although there was some fluctuation, due to variations in the plants and in the number of hours of sunlight previous to sampling, data presented in Tables I and II show that in the content and distribution

TABLE I—TOTAL REDUCING SUGARS IN PERCENTAGE OF DRY WEIGHT  
(FIRST YEAR)

	Leaves	Roots	Stems
August 22	4.25	1.03	1.23
September 6	4.13	1.28	.68
September 18	3.63	1.14	1.03
September 25	4.35	1.73	2.25
October 2	4.20	1.98	1.95
October 16	5.55	1.03	2.63
November 6	3.20	2.25	3.33
November 25	3.30	1.03	2.87
December 12	3.03	3.58	4.85
December 23	2.18	2.60	3.70
January 6	3.35	4.87	3.60
February 2	1.42	6.62	5.37
February 21	3.57	6.95	4.87
March 12	2.35	5.2	3.65
March 30	2.35	4.45	3.07
April 13	3.4	5.87	5.2
April 27	2.12	4.07	5.4
May 11	2.95	5.02	4.52
June 4	3.15	1.6	4.25
June 23	4.4	3.3	5.5
August 12	3.3	2.9	4.3

TABLE II—REDUCING SUGARS IN PERCENTAGE OF DRY WEIGHT  
(SECOND YEAR)

	Leaves	Roots	Stems
September 15	2.56	2.90	2.16
September 28	0.87	2.12	4.42
October 12	4.54	3.05	2.65
October 26	3.14	1.92	2.5
November 10	2.45	3.56	2.4
November 30	4.02	3.64	3.42
December 15	3.93	2.63	4.72
January 4	3.83	7.72	4.86
February 24	2.72	7.44	1.66
March 28	3.88	6.84	1.65
April 28	3.85	2.90	1.82
May 8	2.07	1.0	3.15

of reducing sugars, the plants were similar in the 2 years. During the late summer, when the experiment was begun, and in early autumn, the percentage of reducing sugars in the leaves, 2.18 to 5.55 per cent, was higher than in the roots and stems, 1.0 to 4.85 per cent. During the months of relative inactivity, the proportion was larger in the roots and stems indicating a storage of carbohydrate. This relation existed until

fruiting time when the percentage of reducing sugars in the roots markedly decreased. It was found that yellowing and dead leaves usually contained much less reducing sugars, 0.9 to 1.1 per cent, compared with green leaf tissue, 3.6 to 4.9 per cent. The content of reducing sugars in the roots and stems of strawberry plants was similar to that found in apple spurs (1).

When the floral buds were just large enough to be separated with small scissors, these sugars made up 1.45 per cent. All analyses of floral organs and fruits included the small green leaf-like structures just beneath and surrounding the flower or fruit. There was a consistent increase from the buds (1.45 per cent), flowers (2.31 per cent), to the fruits (3.05 to 5.80 per cent).

Studies of Tables III and IV which record the reducing sugars in grams per 100 plants, reveal that the total weight of these sugars in the

TABLE III—TOTAL REDUCING SUGARS IN GRAMS PER 100 PLANTS  
(FIRST YEAR)

	Total	Leaves	Roots	Stems
August 22 . . . . .	19.38	11.9	7.15	0.33
September 6 . . . . .	13.07	11.64	1.20	0.23
September 18 . . . . .	17.2	15.11	1.63	0.46
September 25 . . . . .	24.59	20.66	2.78	1.15
October 2 . . . . .	31.55	25.32	4.87	1.36
October 16 . . . . .	46.92	41.90	2.26	2.76
November 6 . . . . .	41.86	28.22	7.42	6.22
November 25 . . . . .	33.43	23.99	4.24	5.20
December 12 . . . . .	44.55	20.45	15.86	8.42
December 27 . . . . .	34.11	14.50	13.18	6.43
January 6 . . . . .	40.61	22.43	12.51	5.67
February 2 . . . . .	48.17	7.97	28.53	11.67
February 21 . . . . .	51.7	13.3	30.00	8.30
March 12 . . . . .	33.36	7.98	18.25	7.13
March 30 . . . . .	27.55	7.39	14.86	5.30
April 13 . . . . .	41.28	11.88	20.07	9.33
April 27 . . . . .	25.23	6.49	10.87	7.87
May 11 . . . . .	34.39	12.37	14.93	7.09
June 4 . . . . .	27.63	16.62	3.98	7.03
June 23 . . . . .	41.08	26.18	5.3	9.6
August 12 . . . . .	24.70	14.55	3.2	6.85

TABLE IV—TOTAL REDUCING SUGARS, IN GRAMS PER 100 PLANTS  
(SECOND YEAR)

	Total	Leaves	Roots	Stems
September 15 . . . . .	7.74	4.50	2.4	.84
September 28 . . . . .	6.74	1.82	3.26	1.66
October 12 . . . . .	25.14	15.20	8.30	1.64
October 26 . . . . .	19.74	11.66	5.90	2.18
November 10 . . . . .	31.24	12.20	15.72	3.32
November 30 . . . . .	35.66	16.32	15.64	3.74
December 15 . . . . .	32.22	16.14	10.36	5.72
January 4 . . . . .	40.54	5.82	30.58	4.14
February 24 . . . . .	35.12	4.72	29.2	1.12
March 28 . . . . .	26.92	12.66	22.84	1.42
April 28 . . . . .	15.08	8.12	6.08	1.60
May 8 . . . . .	9.68	5.28	1.70	2.64

leaves is high due not only to the percentage of reducing sugars present, but also to the large total leaf area. At the height of autumnal activity, November 6 to 10, nearly 70 per cent of these sugars are in the leaves, but with the senescence of these organs, 30 to 60 per cent are found in the roots. Possibly a migration of sugars to the roots which seem to be

the principal storage organs of the strawberry (2, 4), took place during January. During the spring when much soluble carbohydrate is needed for the production of new leaves, floral organs, and fruits, these sugars were almost depleted in the roots (Tables III and V).

TABLE V—SUGARS IN FLOWERS AND FRUITS OF THE STRAWBERRY PLANT

	Tissue	Reducing Sugars		Total Sugar (Per Cent)	Total Grams
		(Per Cent)	(Total Grams)		
<i>First Year</i>					
April 3. . . . .	Buds	1.45	0.43	3.35	1.0
April 27. . . . .	Flowers	2.31	2.07	3.90	3.5
May 11. . . . .	Pedicels	3.00	2.02	3.3	2.9
	Fruits	3.05	3.66	3.6	4.3
June 4. . . . .	Pedicels	2.80	2.45	3.7	3.3
	Fruits	5.80	20.00	6.7	22.46
<i>Second Year</i>					
April 28. . . . .	Flowers	1.80	0.81	4.4	1.98
May 8. . . . .	Flowers	1.30	0.29	1.8	0.40
	Pedicels	2.00	0.45	3.2	0.80
	Fruits	2.10	1.22	4.78	2.81

A comparison of the reducing sugar content and the content of total sugars reducing and non-reducing, indicates that the reducing sugars constitute about 40 to 70 per cent of the total amount of sugars.

## ACKNOWLEDGMENT

The author is indebted to Dr. A. E. Murneck for advice throughout this investigation which was conducted in the Department of Horticulture, University of Missouri.

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## Vitamin C and Light<sup>1</sup>

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THE effect of light upon the synthesis of vitamin C (ascorbic acid) during the processes of plant metabolism has never been thoroughly investigated. Several authors have touched upon the sunshine role fortuitously. They have drawn their conclusions indirectly from data designed to ascertain the effect of other factors. The demonstration that the concentration of vitamin C is augmented during the maturation of some vegetables (1, 2) and that larger amounts of vitamin C are present in the periphery than nearer the center of certain fruits and vegetables (3, 4, 5, 6) indicates that light is perhaps one of many factors influencing production of vitamin C. Other investigators have dealt directly with the light factor in connection with researches upon the formation of vitamin C during germination (2, 7, 8, 9, 10). Their results indicate that vitamin C is formed during germination even in complete darkness, but that the amount thus produced is much smaller than is formed if germination and growth take place in the light. Several reports (7, 11, 12) emphasize a direct relation between the content of chlorophyll and that of vitamin C. On the other hand, one investigator (13, 14) reports that sunlight alone does not affect the vitamin C content of apples.

In the course of investigations at the Maine Agricultural Experiment Station upon the vitamin C content of apples during 1936, an effect of light has manifested itself which may be of interest to workers engaged in determining the origin and distribution of vitamin C.

It has been found that the "sunny" side of the apple contains larger amounts of vitamin C than the "shady" side, as determined by the titrimetric method as modified by Bessey and King (15) using 2, 6-dichlorophenol indophenol. In most cases this difference was large enough to be manifest even when the "sunny" side of the apple was peeled while the "shady" side was tested unpeeled. The vitamin C content of apple flesh has been reported as being only 50 to 75 per cent as large as that of the unpeeled apple (14). No attempt was made to correlate the amount of blush on a given variety with the ascorbic acid content. It was observed, however, that the difference was demonstrable in the Golden Delicious variety, the blush of which is so slight as to permit titrimetric determination without preliminary treatment to remove the color.

Fifty pairs of tests were completed using nine varieties of apples.<sup>2</sup> Of these 50 pairs of analyses, the results were divided into three groups. The mean differences were computed by Student's method.

(a) Eighteen pairs of determinations on comparable peeled samples of apples.

The ascorbic acid content of the "sunny" side exceeded that of the "shady" side in 15 of the 18 pairs of tests. The mean difference

<sup>1</sup>Paper 226 of the biological laboratory of the Maine Agricultural Experiment Station.

<sup>2</sup>Averages for the groups varied from .0785 mg/gm for the "sunny" side unpeeled to .0449 mg/gm for the "shady" side unpeeled.

in ascorbic acid value was  $.0150 \pm .0022$  mg/gm with odds of 6,498 to 1 that the difference was significant.

- (b) Eleven pairs of determinations on unpeeled comparable samples.

The ascorbic acid content of the "sunny" side was greater than that of the "shady" side in 10 of the 11 pairs of analyses. The mean difference was  $.0252 \pm .0028$  mg/gm with odds of 9,999 to 1 that the difference was significant.

- (c) Twenty-one pairs of determinations comparing the peeled "sunny" with the unpeeled "shady" side of the same apple.

The ascorbic acid content of the "sunny" side was higher than that of the "shady" side in 17 of the 21 pairs of analyses. The mean difference was  $.0139 \pm .0022$  mg/gm with odds of 3,145 to 1 that the difference was not due to chance alone. Obviously light exerts an influence powerful enough to overshadow the fairly large reported differences between the peripheral portion and the central portion of the apple.

It is possible that this variation within the same fruit partially accounts for the lack of agreement frequently noted in published data on the vitamin C content of a given fruit or vegetable.

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## Vitamin C Content of Spinach<sup>1</sup>

By C. F. DUNKER and C. R. FELLERS, *Massachusetts State College, Amherst, Mass.*

**F**RESH spinach ranks among one of our best vegetable sources of vitamin C. In summer it is eaten fresh, while in winter canned or frozen spinach is used.

References to literature have shown that investigators have found spinach to be a good source of vitamin C. The majority of workers have concentrated their experimental work either on fresh raw or on canned spinach. The object of this paper is to determine the relative changes and losses of vitamin C which occur in fresh raw spinach due to the processes of cooking, freezing, canning, and drying.

Reports on vitamin content of foods often show enormous losses of vitamin C upon cooking. An essential point in this paper is to demonstrate that a great part of the loss of vitamin C in cooking spinach is due to its solution in the cook water rather than solely to oxidation by heating.

Investigators have differed in the amount of vitamin C which they have found in spinach. Tressler, Mack and King (9) found that the amount of vitamin C in raw spinach varies from 0.38 to 0.77 milligrams per gram, depending on the variety. Kifer and Munsell (4) determined the vitamin C content of raw spinach to be about 0.5 milligram per gram. Wasson (10) and Eddy, Kohman and Carlsson (3) concluded that raw spinach contained over 0.5 milligram per gram. Pierson (6) has shown that canned spinach is a fair source of vitamin C, being about one-third as potent as is fresh spinach. She found that it is necessary to feed guinea pigs 5 grams of canned spinach daily to protect them from scurvy. Tressler, Mack and King (9) demonstrated that spinach grown in muck soil contained 50 per cent less vitamin C than did the same variety grown on upland soil. They also showed that spinach stored at 1 to 3 degrees C lost little ascorbic acid in several days, whereas when stored at room temperature, it lost 50 per cent of its vitamin C content in 3 days and almost all in 7 days.

### EXPERIMENTAL PROCEDURE

Semi-weekly shipments of iced fresh raw spinach were made from the Birds Eye packing plants in Bridgeton, New Jersey to Amherst. Upon arrival the samples were examined for ascorbic acid content by the Tillmans, Hirsch and Hirsch (8) titration method as modified by Bessey and King (2), and Mack and Kertesz (5). Simultaneously, a second portion of the same lot of spinach was quick-frozen in the Birds Eye laboratories, while a third portion of the same lot of fresh spinach was canned. These lots were later shipped to Amherst and their ascorbic acid content determined.

One pound portions of the fresh spinach and of the frozen spinach were cooked in water and in steam, and the amount of vitamin C retained was determined. The amount of free liquid (cook water)

<sup>1</sup>Contribution No. 339, Massachusetts Agricultural Experiment Station.

remaining was measured and its ascorbic acid content per cubic centimeter was determined. In this way it was possible to find the amount of ascorbic acid lost into the "cook water" due to its solution from the spinach. For the sake of simplicity the results are expressed on a 100 gram basis.

Several portions of spinach were dehydrated and the ascorbic acid therein determined.

Determinations for reversibly oxidized ascorbic acid in cooked and in canned spinach were made. The method used was the usual one. Hydrogen sulfide gas was passed for  $\frac{1}{2}$  hour through the ascorbic acid solution obtained from extraction of the spinach with a mixture of 2 per cent metaphosphoric acid and 3 per cent tri-chloroacetic acid. After this the solution was treated with carbon dioxide gas until no hydrogen sulfide remained, and then titrated for ascorbic acid content.

The ascorbic acid in cooked spinach was determined also by the iodine titration method.

Animal assays with guinea pigs by the Sherman method (7) were carried out on fresh raw, fresh cooked, and canned reheated spinach.

## RESULTS

*Effect of Freezing, Cooking and Canning:*—Good fresh raw spinach contains from 400 to 450 international units of vitamin C per ounce. In one series of tests (Table I) the process of blanching and quick-freezing spinach caused a loss of about 45 per cent. However, once frozen there is almost no further loss of vitamin C in the spinach over a period of many months.

TABLE I—EFFECT OF FREEZING, COOKING AND CANNING ON THE ASCORBIC ACID CONTENT OF SPINACH\*

Sample Number	Raw		Steam Cooked		Water Cooked		Frozen		Cooked Frozen (With Water)		Canned	
	Mg Per Gram	I. U. Per Ounce	Mg Per Gram	I. U. Per Ounce	Mg Per Gram	I. U. Per Ounce	Mg Per Gram	I. U. Per Ounce	Mg Per Gram	I. U. Per Ounce	Mg Per Gram	I. U. Per Ounce
1	.583	331	.592	347	.266	151	.538	305	.293	166	.291	165
2	.792	448	.312	183	.193	109	.242	137	.203	115	.229	130
3	.736	417	.393	223	.122	69	.418	237	.215	122	.269	152
4	.821	465	.506	287	.295	167	.445	252	.262	149	.317	180
5	.644	364	.519	292	.338	191	.542	307	.416	236	.276	156
6	.593	336	.294	224	.352	200	.450	255	.209	117	.270	153
7	.946	537	.742	420	.318	180	.450	255	.287	162	—	—
8	1.142	647	.742	420	.298	169	.458	260	.218	124	—	—
9	1.101	628	.692	392	.323	183	.596	338	.412	233	—	—
10	1.087	616	.742	420	.256	145	.552	313	.337	191	—	—
Average	.844	478	.563	320	.276	156	.469	266	.285	161	.275	156

\*Different set of samples from those in Table IV and Fig. 1

Cooked spinach lost 32 to 67 per cent of its original vitamin C content (Table II), depending on the method of cooking. It seems that the greater the amount of water used in cooking the spinach, the greater is the amount of vitamin C which dissolves from the spinach, and hence the greater is the loss of vitamin C. Steam cooking spinach

using 100 cubic centimeters of water caused a loss of 32.4 per cent of vitamin C, of which 10.3 per cent was due to the solubility of the vitamin C in the "cook-water". Water cooking spinach in 900 cubic centimeters of water caused a loss of 67.4 per cent of vitamin C, of which close to 16 per cent was due to loss of the vitamin in the "cook water". Attention is directed to the fact that if the "cook water" were not discarded, in the case of steam cooked spinach, more than 10 per cent of the vitamin C would still be available, whereas in the case of the water-cooked spinach over 15 per cent could be saved. Frozen spinach upon being cooked loses less than 8 per cent of its vitamin C due to oxidation solely. At least 30 per cent may be recovered from the "cook-water".

TABLE II—LOSS OF VITAMIN C DURING COOKING SPINACH (10 SAMPLES)

Description	Solid Portion		Liquid Portion			Total Ascorbic Acid Retained in Spinach and in Cook Water (Mg. per 100 Grams)	Loss of Ascorbic Acid by Oxidation Alone
	Mg per 100 Grams	Loss (Per Cent)	Average Amount (Cc)	Loss per 100 Gm Spinach (Mg)	Liquid Loss (Per Cent)		
Raw	84.4	—	—	—	—	—	—
Steam cooked	56.3	32.4	22.8	8.7	10.3	65.0	22.1
Water cooked*	27.6	67.4	158	13.2	15.7	40.8	51.7
Frozen	46.9	44.4	—	—	—	—	—
Frozen cooked*	28.5	39.6†	105	14.7	31.7	43.2	7.9

\*1 pound of spinach cooked with 2 cups (450 cubic centimeters) of water.

†Loss with reference to the frozen sample; loss with reference to raw sample is 67 per cent

The canning of spinach causes loss of 67 per cent of the vitamin C originally present. The average of 18 samples of canned spinach showed 168 international units of vitamin C per ounce. Once spinach is canned, it retains its vitamin C very well over long periods of storage. Dehydrated spinach contains no vitamin C.

*Dehydro-Ascorbic Acid*.—Referring to Table III it is evident that no dehydro-ascorbic acid is present in the spinach. This test was carried out only on the extracted vitamin C solution, in that it is very difficult to free plant tissues from hydrogen sulfide.

TABLE III—DETERMINATION OF REVERSIBLY OXIDIZABLE (DEHYDRO) ASCORBIC ACID IN SPINACH

Variety	Ascorbic Acid Before Treatment (Mg per Gram)	Ascorbic Acid After Treatment (Mg per Gram)
Frozen, cooked	.064	.064
Frozen, cooked	.056	.056
Frozen, cooked	.067	.065
Canned, reheated	.234	.232

*Iodine Titration Results*.—The average of 10 samples of spinach, titrated with iodine to determine the ascorbic acid, was 0.21 milligram of ascorbic acid per gram, as compared with 0.17 milligram of ascorbic acid per gram determined by the indophenol titration method on the same set of samples. The iodine method gives values 15 to 20 per cent



higher than those of the indophenol method. The iodine titration is advantageous in that it gives a clearer, sharper end point.

*Comparison of Dye Titration and Animal-Bioassay Methods:*—When both methods were compared good checks were obtained with fresh raw and with fresh cooked spinach (Table IV). Although only fair checks were obtained with the canned spinach, still the results are in agreement with similar work done by Pierson (6) who determined the daily protective level of canned spinach at 3.0 grams per guinea pig. As much as 15 per cent loss from oxidation of the ascorbic acid in canned spinach placed in the feed containers took place before the guinea pigs ate the 6.0 grams of spinach being fed them on the highest level. A second explanation is based on the investigation of Addinall (1), who found irreversibly oxidized ascorbic acid, which is physiologically inactive, has even stronger reducing properties than has ascorbic acid itself. It may be that upon storage of canned spinach, and especially of frozen spinach, much of the active ascorbic acid may have changed to the inactive irreversibly oxidized ascorbic acid, which is still able to reduce the indophenol dye. In this way the dye titration would indicate that larger amounts of active ascorbic acid were present than actually was the case, and would consequently give higher results than the animal bioassays.

TABLE IV—COMPARISON OF DYE TITRATION AND ANIMAL BIOASSAY METHODS FOR THE DETERMINATION OF ASCORBIC ACID IN SPINACH

Treatment of Spinach	Number of Samples	Titration Value of Ascorbic Acid (Mg per Gram)	Calculated Protective Level From Titration* (Gram)	Vitamin C per Ounce per Titration Data (I. U.)
<i>Dye Titration Method</i>				
Fresh . . . . .	22	.77	.65	435
Fresh cooked . . . . .	21	.40	1.25	226
Frozen . . . . .	9	.31	1.6	175
Canned . . . . .	12	.28	1.8	158
Dehydrated . . . . .	3	0	none	none

Treatment of Spinach	Feeding Levels Used (Gram)	Probable Protective Level for Guinea Pigs (Gram)	Estimated Vitamin C Content From Guinea Pig Assay (I. U. per Ounce)	Sherman Scurvy Score	Number of Pigs
<i>Biological Assay Method</i>					
Fresh . . . . .	1.5	0.7 to 1.0	407	0, 0, 0	3
Fresh, cooked . . . . .	3.0	1.4 to 2.0	204	0, 0, 0	3
Canned . . . . .	2.0	2.5 to 3.0	113	1½, 1½, 1½	3
Canned . . . . .	3.0	2.5 to 3.0	113	0, 0, 0	3

\*Based on daily requirement of .5 milligram ascorbic acid per guinea pig.

As seen in Table IV, 1.5 grams of fresh raw spinach, 3.0 grams of fresh cooked spinach and 3.0 grams of canned reheated spinach contained sufficient ascorbic acid to fully prevent guinea pigs from scurvy over the period of the experiment.

## SUMMARY AND CONCLUSION

Fresh raw spinach contains from 400 to 450 international units of vitamin C per ounce. The loss of ascorbic acid on cooking is 33 to 67 per cent depending on the amount of "cook water" use; in general the larger the latter, the greater the loss. From 10 to 30 per cent of the original vitamin C in the spinach can be recovered from the cook water. The canning of spinach causes loss of 60 to 65 per cent of its vitamin C. Freezing and incidental operations cause losses approximating 45 per cent. Dehydration results in total loss. No dehydro-ascorbic acid was found in either frozen or canned spinach. Iodine titration values for ascorbic acid in spinach are about 19 per cent higher than the indophenol titrations. Satisfactory checks were obtained on the fresh raw and fresh cooked spinach by the dye-titration and the animal bioassay methods. The dye titration method gave somewhat higher results with the canned spinach.

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## Results From Three Methods of Applying Fertilizer to Certain Vegetables

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THE application of fertilizer in bands to the sides of vegetable plants by machine has been found by Chucka (1), Cumings (2), Sayre (3) and other investigators to be often superior to other methods of distribution. The studies outlined in this paper were conducted to determine if the results in other states were applicable to Florida conditions, to compare local methods of applying fertilizer against placement of materials in bands to the sides of the seed and to observe the effect of the distribution of the fertilizer on the root growth of several vegetables.

The fertilizer materials in this experiment were distributed by three methods. First, the local method of placing the mixture in the furrow row and mixing it with the soil was employed. The second method consisted of broadcasting the materials over the entire area and in the third method the fertilizer was distributed by an attachment on a one-row planter. The fertilizer was placed in 2-inch bands 2 inches to the side of the seed, the bands being on a level to 2 inches below the seed. The latter method will be referred to in this paper as the machine method. All treatments were replicated four times.

Six vegetable crops were used in this study. Tomatoes and lettuce were grown for only one season, while potatoes, beans, peppers and cucumbers were grown for 2 years. All crops grown at Gainesville were located on Arredondo loamy fine sand and Alachua fine sandy loam. Investigations with potatoes were conducted in 1938 at LaCrosse, Florida, a specialized potato growing area, on soil classified as Blanton fine sand and Orlando fine sand.

All crops grown during the 1937 season were retarded in their growth by lack of moisture and the yields were below normal.

Table I shows that, at Gainesville, the highest average yield of U. S. No. 1 potatoes was 118 bushels per acre and was obtained from the plots fertilized by the broadcast method. The plots fertilized with the machine placed materials gave an average yield which was 28 bushels lower, while the furrow row method produced 46 bushels less than the broadcast method. At LaCrosse the following year the plots on the Blanton fine sand when fertilized by the machine method gave the greatest yield of U. S. No. 1 potatoes. These plots yielded an average of 177 bushels per acre. This yield was not significantly greater than the yield of 173 bushels from the furrow row method. Both, however, proved superior to the yield of 148 bushels per acre from the plots fertilized by the broadcast method. In the same year on Orlando fine sand at LaCrosse the potatoes yielded 146 bushels of U. S. No. 1 per acre when the fertilizer was placed in the furrow row. Neither of the other methods of fertilization was found to be superior on this soil, the machine method producing 136 bushels, and the broadcast method 120 bushels.

TABLE I—YIELD IN BUSHELS PER ACRE OF U. S. No. 1 GRADE VEGETABLES AS AFFECTED BY FERTILIZER APPLICATION

Method of Application	Year	Cucumbers		Beans		Peppers	
		Bushels	Odds	Bushels	Odds	Bushels	Odds
In bands to the side . .	1937	63	27:1	92	4:1	89	6:1
	1938	94	1500:1	222	39:1	228	1:1
In the furrow row . . .	1937	36	81:1	115	4:1	70	5:1
	1938	82	15:1	228	75:1	264	8:1
Broadcast . . . . .	1937	16	*	105	*	80	*
	1938	66	*	183	*	229	*

Method of Application	Year	Tomatoes		Potatoes	
		Bushels	Odds	Bushels	Odds
In bands to the side . . . . .	1937	106	2:1	90	18:1
	1938	—	—	177**	9999:1
In the furrow row . . . . .	1937	101	4:1	135†	10:1
	1938	—	—	72	38:1
Broadcast . . . . .	1937	121	*	148†	157:1
	1938	—	—	118	121:1
				148**	*
				120†	*

\*Odds determined by Student's Method; Broadcast treatment used for comparison. Odds less than 20 to 1, not considered significant.

\*\*On Blanton fine sand

†On Orlando fine sand.

Plots fertilized by the furrow row method gave the highest yield of beans in 1937 at Gainesville, but their average yield of 115 bushels per acre was not significantly more than the average yield from the plots of the broadcast and machine method. These yielded 105 and 92 bushels per acre, respectively. In 1938, the beans growing on the furrow row method plots gave the highest yield of 228 bushels per acre. This, however, was not much higher than the bean yield of 222 bushels from the machine method. Yields from these two methods were significantly greater than the yield of 183 bushels from the broadcast method.

With cucumbers significantly higher yields were received for both years by the application of fertilizer by the machine method over the broadcast method. In 1937, the cucumber plots fertilized by the machine method yielded 63 bushels of U. S. No. 1 cucumbers per acre as compared with 36 bushels from the furrow row method and 16 bushels from the broadcast method. In the 1938 season higher cucumber yields were obtained. The plots treated by the machine method produced 93 bushels of U. S. No. 1 cucumbers per acre as compared with 83 bushels of cucumbers from the furrow row method and 63 bushels from the broadcast treated plots.

In the 2 years of the experiment no method of fertilizer application was found to give yields significantly larger than broadcast method with peppers.

In the 1 year that they were grown tomatoes gave a yield of 121 bushels of U. S. No. 1 an acre when the fertilizer was broadcast. This method of application was not significantly better than the machine or furrow row method.

The series of plots planted to lettuce gave highest yields when the plots were fertilized by the machine method but the yields were not

significantly higher than the yields obtained from the furrow row or broadcast method of application. These results can only be taken as indications for future experiments.

In all of the experiments conducted, the only indication of fertilizer injury observed was on tomatoes fertilized by the furrow method.

In order to study further the effect of fertilizer applied by the three methods, the root distribution of cucumbers, beans, potatoes, and lettuce, was studied. This study was accomplished by digging a trench in front of each observed plant. The soil was then removed with a small pointed piece of metal and diagrammatic drawing of the roots made as they were uncovered. On all drawings only one-half of the horizontal growth was shown.

The roots of the bean plants where the fertilizer was applied by the machine method were located 3 to 8 inches from the surface of the soil as can be seen in Fig. 1. The roots in many cases doubled back on their original route, thus staying in the band of fertilizer. Where the fertilizer was placed in the furrow row the roots of the bean plants were found lying on an average within 5 inches of the main axis of the plant row. The plants which were grown on the broadcast treatment had their roots massed near the surface, the majority of them being in the top 4 inches.

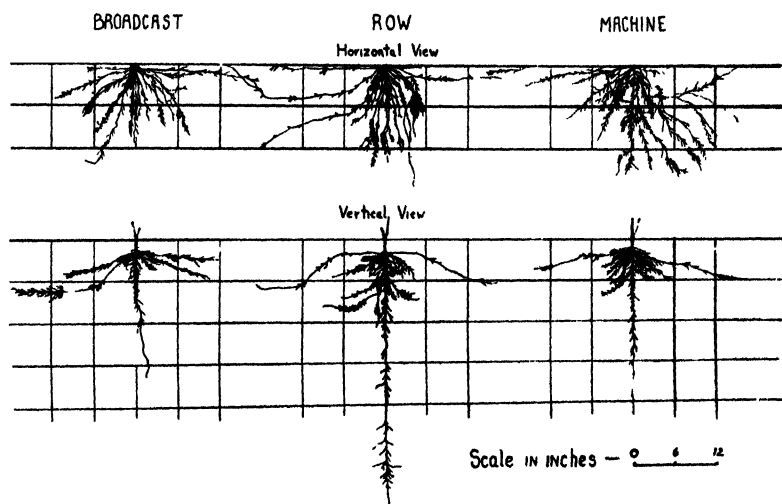


FIG. 1. The effect of fertilizer distribution on the root growth of beans.

The roots of the potato plants on the broadcast treatment were widely spread as shown in Fig. 2. There seemed to be no definite area of root concentration. However, with the machine treatment the roots showed a noticeable concentration in the region of the fertilizer bands. The plants in the furrow row method had roots in the fertilizer in the furrow row but their concentration was not as definite as observed in the machine method plots.

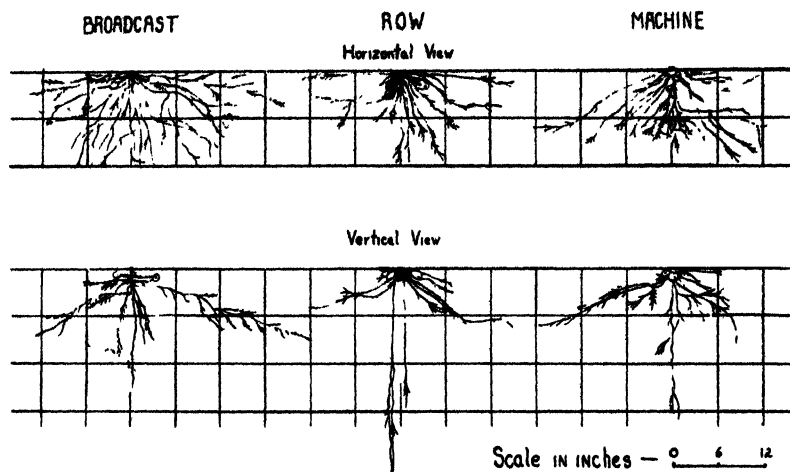


FIG. 2. The effect of fertilizer distribution on the root growth of potatoes.

The roots of all crops observed were found to grow vigorously in the areas where the fertilizer salts were concentrated. The distribution of the fertilizer seemed to have a limiting effect on the area covered by the roots.

The results of this experiment would indicate that crops requiring a short growing season, such as cucumbers, produce greater yields when the fertilizer is applied by the machine or row method. Evidently the nutrient materials were available more quickly to the roots. The fertilizer that is broadcast appears to be more completely utilized by crops having a long growing season such as peppers and tomatoes. The natural fertility of the soil type and the moisture holding capacity plays an important role in the effectiveness of the method of fertilizer application employed by the grower. This was shown from the results with potatoes. The broadcast method gave higher yields of U. S. No. 1 potatoes in 1937 when irrigation was employed at Gainesville; however, under drier conditions at LaCrosse in 1938 on one soil type the furrow row method gave the highest yield. On a different soil type the machine method produced the highest yield of U. S. No. 1 potatoes.

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## Influence of Summer Legumes on the Early Spring Crop of Snap Beans in South Alabama

By L. M. WARE, *Alabama Agricultural Experiment Station, Auburn, Ala.*

THE commercial truck crops of South Alabama are planted too early in the year to permit the use of winter legume crops for soil-improvement purposes. Summer legumes planted the year before, therefore, offer about the only practical way of adding nitrogen to the soil by natural means and of maintaining the organic content of the soil at a favorable level. The high temperatures during the larger part of the year conducive to rapid decomposition, the high rainfall of the area capable of heavy leaching, and the early season of planting of truck crops in South Alabama before a spring supply of nitrates can be built up, are factors any one of which might greatly affect the benefits derived by crops grown 1 year from legumes turned under the previous year.

To obtain definite data on the influence of summer legumes on the early truck crops in South Alabama, a series of experiments was started in 1931 at the Gulf Coast Substation, at Fairhope. Snap beans was one of six crops used in the experiment. The crops were rotated in two groups of three crops each. The experiment included five treatments which were as follows:

1. Non-legume removed from land; no commercial nitrogen applied to beans.
2. Legume crop turned in the fall; no commercial nitrogen applied to beans.
3. Legume crop turned in the fall; one-half standard rate of commercial nitrogen applied to beans.
4. Legume crop turned in the fall; standard rate of commercial nitrogen applied to beans.
5. Non-legume crops removed from land; standard rate of commercial nitrogen applied to beans.

The summer cover crops have been grown each year following the spring truck crop. *Crotalaria* has been used each year as the legume crop. For the non-legume crops corn was grown in 1931, 1932, and 1933. Sudan grass in 1934 and 1935, and Hegari in 1936, 1937, and 1938. All commercial fertilizers were added to the truck crop. Five hundred pounds of superphosphate and 96 pounds of muriate of potash per acre were added in each treatment. Forty-eight pounds per acre of nitrogen were used as the standard rate for nitrogen. All treatments were run in triplicate on 1/60-acre plots.

In Table I are given the yields of beans and the weights of legumes turned under each year from 1932 through 1938. There were no weights of legumes taken in 1931; the yields, however, were small according to observational notes. In 1932, following the turning of the first crop of legumes, there was only 1 bushel difference recorded in yield of beans due to the legume. In 1933, following a 2.2 ton crop of *crotalaria*, only a five-hamper increase in beans was recorded for the

TABLE I.—YIELD OF BEANS WITH AND WITHOUT SUMMER LEGUMES AND WITH DIFFERENT AMOUNTS OF NITROGEN

Treatment		Yield per Acre*											
Fertilizer 800 Pounds per Acre	Legume	1932		1933		1934		1935		1936		1937	
		Beans (Bushels)	Legume (Pounds)	Beans (Bushels)	Legume (Pounds)	Beans (Bushels)	Legume (Pounds)	Beans (Bushels)	Legume (Pounds)	Beans (Bushels)	Legume (Pounds)	Beans (Bushels)	Legume (Pounds)
N-P-K													
0-10-6.	None	51	—	63	—	63	—	60	—	67	—	11	—
0-10-6.	Crotalaria	52	4470	68	18,418	129	27,871	163	24,001	152	23,609	31	18,601
3-10-6.	Crotalaria	49	6150	130	10,900	167	25,621	222	35,010	188	23,130	30	19,109
6-10-6.	Crotalaria	59	5430	139	15,419	246	27,360	239	32,641	188	22,320	29	17,791
6-10-6.	None	50	—	159	—	207	—	191	—	180	—	—	—

\*Beans in bushels; legume in pounds green material



legume. These differences were not of practical significance. In 1934, following a 9.2 ton crop of crotalaria, there was an increase of 66 bushels per acre of beans attributable to the legumes. Heavy crops of legumes have been produced each year since 1934. Increases in yield of beans attributable to the legume were 103 bushels per acre in 1935, 85 bushels in 1936, and 72 bushels in 1938. There was practically a crop failure in 1937. The increase in yield attributable to legumes was determined by the difference in the yield of beans on plots receiving no commercial nitrogen and no legumes and those receiving legumes but no commercial nitrogen.

It should be noted especially that three legume crops were turned before a significant increase in the yields of beans was obtained as a result of the turning of the legume crops. This would not appear so significant but for the fact that other truck crops, especially Irish potatoes in repeated tests, have behaved in a similar way, although very heavy legume crops have been turned from the beginning. It thus becomes well established in South Alabama that the turning of one or two summer legume crops has little effect on the yield of early spring crops. It is obvious, however, that the continuous use of a summer legume in a definite system of soil improvement has ultimately resulted in a material increase in the yield of early snap beans.

The yield of beans on legume plots receiving no commercial nitrogen reached a good commercial production by the time the third crop of legumes had been turned. The yield of beans after the third legume crop was 129 bushels, after the fourth legume crop 163 bushels, and after the fifth legume crop 152 bushels. The yields on legume plots without any commercial nitrogen were higher after the third legume crop had been turned than the average of that section of the State with a complete fertilizer.

Although good commercial yields of beans have been obtained from turning summer legumes without any commercial nitrogen, it may be seen that in no year have maximum yields been obtained without the addition of some commercial nitrogen. The yield of the legume plots receiving no commercial nitrogen has never equalled in any year the yield of plots receiving one-half the standard rate of nitrogen with legumes nor has it equalled the yield of those plots receiving the standard rate of nitrogen without a legume.

It is of practical importance and of experimental interest to note that after the fourth legume crop had been turned, the yield of beans each year on legume plots receiving one-half the standard rate of commercial nitrogen has been materially higher than on plots receiving a standard rate of commercial nitrogen but with no legume crop. This difference averaged approximately 16 bushels per acre for the last three normal crops. In this connection it should be stated that in a related experiment at the same station with fertilizer ratios for beans the 5-year-average yield for a standard rate of nitrogen was 33 hampers per acre more than for the half standard rate where legumes were not turned in either treatment. This would mean, at least by inference, that the legume used along with a half standard rate of nitrogen has been responsible for an increase in yield of about 49 bushels per acre.

Of still further practical and experimental importance are the comparative yields of beans from plots receiving standard amounts of nitrogen without legumes and those receiving standard amounts of nitrogen with legumes. It may be seen by referring to Table I that by the time several legume crops have been turned, plots receiving a standard rate of nitrogen with legumes were producing a considerably higher yield than plots receiving a full rate of nitrogen without legumes; this difference amounted to 39 bushels per acre in 1934 and 48 bushels per acre in 1935. It should be noted, however, that by 1936 this difference had dropped to 8 bushels and by 1938 the legume plots with a standard rate of nitrogen were producing 28 bushels per acre less than those receiving a standard rate of nitrogen without a legume. It remains to be determined from the yields in future years whether this downward trend in yields of beans continues on plots receiving both legumes and a standard rate of nitrogen. A laboratory study of the seasonal levels of nitrates now planned should give some indication of the relation of available nitrogen to this behavior.

Laboratory tests in the late fall of 1937 indicated very little difference in the amount of available phosphorus in plots on which heavy cover crops have been turned and in those from which the cover crops have been removed. All plots have received, however, liberal applications of phosphorus. As would be expected total nitrogen was higher in plots on which legumes had been turned, although the difference was not great. In spite of the heavy crops of legumes turned for 5 years, the increase in the organic content of the soil, as determined by the ignition method, has been negligible.

That the seasonal nitrate supply in the soil may be playing a rather important part in the yields of plots receiving commercial nitrogen with legumes and without legumes is indicated by the relative yields for the consecutive years of the experiment on plots receiving standard rates of nitrogen and half rates of nitrogen where both plots have received legumes. The legume plots receiving a standard rate of nitrogen produced 9 bushels per acre more in 1933, 79 bushels more in 1934, and 17 bushels more in 1935 than the legume plots receiving only one-half the standard rate of nitrogen. In 1936 the yields for these two treatments were identical. In 1938 the legume plots receiving the standard rate of nitrogen produced 39 bushels per acre less than the legume plots receiving the half standard rate of nitrogen. Since there has been approximately the same quantity of organic material added to the soil in these two treatments and since the only difference has been in the amount of nitrogen added, it suggests very strongly that nitrogen is playing a rather important role in the character of the relative yield pattern as it appears at this stage of the experiment. Whether the effect of nitrogen is direct or whether it is indirect has not been determined as yet. It is altogether likely that the addition of the different amounts of nitrogen added each year has affected the amount and character of the biological activities in the soil, which in turn have affected the character of the organic material, the degree of decomposition, the availability of minerals, and the extent of the competition of micro organisms and higher plants for both major and minor mineral elements.

## Studies of Mature Asparagus Plantings with Special Reference to Sex Survival and Rooting Habits

By A. F. YEAGER and D. H. SCOTT, *North Dakota Agricultural Experiment Station, Fargo, N. D.*

A 35-YEAR-OLD asparagus planting on heavy clay soil at the North Dakota Agricultural Experiment Station provides much of the material for this paper. The plantation, set in 1902, is still in good condition. During a 15-year period of sub-normal rainfall, with an average precipitation of less than 18 inches, previous to 1938 the bed produced an average of  $2,969 \pm 224^1$  pounds of asparagus per year per acre when cut at ground level for a season of 5 to 6 weeks.

After 35 years these asparagus plants should give an indication as to their rooting habits. Observations showed many of the crowns had spread to cover an area of 5 feet in diameter. Crowns of such plants, when maintained for so long a time, may suggest the depth at which the plants tend to establish themselves. This might be an indication of how deep to plant asparagus. Excavations showed the crowns to be an average of 5 inches below the surface. Roots from these crowns penetrated to a maximum depth of 6 feet 6 inches, which may be compared to less than a 5-foot penetration for the average of 31 species of trees and shrubs on the same soil (6). Only one species of tree, the apple, rooted to a greater depth. The deeper penetration reported by Weaver (5) in Nebraska probably resulted from differences in the soil.

A count of the staminate and pistillate plants in the 35-year-old planting of nearly 2,000 individuals showed a ratio of 2.5 staminate to one pistillate.

These counts were made at blooming time when plant differences, which were quite marked in the old planting, could be seen easily; and the group of shoots, originating from one crown were counted as a single plant. It was noted that the average staminate crown occupied far more area than the average pistillate.

A nearby 15-year-old planting showed 1.4 staminate to 1 pistillate. Assuming an initial ratio of 1 to 1, which is considered normal by Thompson (4) and others, there is apparently a much greater mortality among the pistillates. This is in agreement with the suggestion of Böttner (1) who states that staminate are the stronger and that the more vigorous tend to crowd out the weaker, but is contrary to the findings of Malhotra (2). Staminate plants have been reported by Robbins and Jones (3) as the more productive. In this old planting when it was 20 years of age, 50 pistillate crowns produced .38 pound per crown, while 50 staminate produced 1.31 pound for the single season. Since it was thought that the staminate plants might have overgrown the pistillate ones in this mixed planting, a new bed was established in which 2-year-old crowns were separated as to sex. A 300-foot row was planted to pistillate individuals, a similar row to staminate, and a third one to mixed plants. At the close of 12 cutting seasons, considering the yield of the mixed planting to be 100 per cent, it was

<sup>1</sup>Standard error is used in this paper.

found that the staminate had produced  $123 \pm 3.7$  per cent, while the pistillate had produced  $68.1 \pm 4.4$  per cent, thus demonstrating the superior productivity of staminate plants when grown alone.

In a variety trial four varieties were grown in comparison, namely Barr's Mammoth, Giant Argenteuil, Palmetto and Mary Washington. During the first two cutting seasons, when the planting was in its third and fourth years, Mary Washington produced nearly double the yield of any of the others. After this, for a period of 10 years there was no significant difference in the yields, except in the case of Palmetto, which was significantly lower than the others.

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## Response of Four Vegetable Crops to Phosphate Fertilizer in Southern Ohio

By JOHN BUSHNELL, *Ohio Agricultural Experiment Station, Wooster, Ohio*

A FERTILIZER experiment with early cabbage, tomatoes, cucumbers, and sweet corn has been in progress for 24 years at the Washington County Experiment Farm, located near Marietta in southeastern Ohio.

The crops are grown in rotation, thus affording an excellent comparison of the response of the crops to the various fertilizer treatments.

The soil, which varies from loam to sandy loam, is low in organic matter but relatively high in phosphates and potash. When the experiment was started in 1915, however, the soil of the farm was reputed to be in a low state of fertility, at least in comparison with neighboring farms.

During the first 16 years of the fertilizer experiment, one of the significant results was the difference between sweet corn and the other crops in response to superphosphate. The cabbage, tomatoes, and cucumbers responded from the outset, but sweet corn showed no significant effect during the entire 16 years. Sweet corn was evidently able to obtain its needed phosphate from the native supply of the soil. Most of the plots were heavily limed, because it was known that cabbage needed lime on this soil, and this may have been a factor in the availability of the phosphate to the sweet corn. Nevertheless, in its ability to use the native soil phosphate, sweet corn was in a distinctly different class from the other three crops.

### EFFECTIVENESS OF RESIDUAL PHOSPHATE

At the end of 16 years some drastic changes were made in the plan of the fertilizer treatments. The check plots, previously unfertilized, were given 1,000 pounds per acre of 8-12-8. One of the previously phosphated plots was given an 8-0-8. In the rearranged plan, then, beginning in 1931, there was (a) a continuously phosphated plot, (b) a plot first phosphated in 1931, and (c) a plot on which phosphating was discontinued in 1931.

In the years immediately following, on the plot where phosphating was discontinued, the residual phosphate was remarkably effective; none of the crops evidenced any need for further phosphate for at least 5 years. In other words, an available residue had been established on this plot by 16 annual applications of 400 pounds per acre of 16 per cent superphosphate.

The amount of this residual phosphate accumulating during the 16 years can be roughly estimated by assuming that the crops removed 10 pounds of phosphoric acid per year. The total phosphoric acid applied was 64 pounds per year, a total of 1,024 pounds in 16 years. The crops removed about 160 pounds leaving a residue of about 864 pounds per acre. In the terminology of soils investigators, this accumu-

lation of 864 pounds was evidently more phosphoric acid than the soil could fix in an unavailable form, at least as far as the crops grown here are concerned.

TABLE 1—LAG IN THE EFFECT OF SUPERPHOSPHATE FERTILIZER (AVERAGE ANNUAL YIELD IN POUNDS PER ACRE FOR THE 4 YEARS, 1931 TO 1934)

	Superphosphate Applied		
	Every Year 1915 to 1934	None After 1930	Beginning 1931
Cabbage	22,920	24,420	19,350
Tomatoes	7,915	8,176	6,950
Cucumbers	3,110	3,900	2,710
Sweet corn	4,350	4,600	4,240

#### INEFFECTIVENESS OF THE BROADCAST APPLICATIONS OF SUPERPHOSPHATE

During the same years that the residual phosphate was highly available where phosphating had been discontinued, the superphosphate applied to the check plots was surprisingly ineffective. The annual application, beginning in 1931, was 600 pounds of 20 per cent superphosphate per acre. But not until 5 years or more had elapsed were the yields of cabbage, tomatoes, and cucumbers on these plots equal to the yields on the continuously phosphated plots. In other words, this broadcast application of superphosphate did not supply the needs of these crops until a considerable residue had accumulated.

The accumulation in 5 years, assuming again that the crops removed about 10 pounds of phosphoric acid per year, was about 110 pounds per year, or about 550 pounds per acre. The interpretation is that the soil fixed the phosphate for the first 5 years in a form unavailable to cabbage, tomatoes, and cucumbers, but this fixing capacity was saturated after something like 550 pounds of phosphoric acid per acre had accumulated.

In the light of the modern trend toward hill and row application of fertilizer, the broadcasting used here may be considered an antiquated procedure. The results on the check plots may even be cited as an example of the ineffectiveness of broadcast applications. Nevertheless, the results obtained here have demonstrated the possibility of raising the phosphate level of this soil to the point where phosphate is evidently available throughout the entire plowed layer. The level has even been raised to the point where crops were successfully grown without a current season application of phosphate in the fertilizer. On soils where this is possible it would seem that the emphasis should be placed upon maintaining the proper phosphate content of the soil as a whole rather than attempting to obtain localized high concentrations by row or hill application.

#### THE AMOUNT OF WATER-EXTRACTABLE PHOSPHATE

As would be expected, the plots which have ample phosphate for all of the crops showed a high phosphorous content when the soil was tested by ordinary quick laboratory methods. Consequently, some

preliminary tests were made with water extracts. A considerable amount of water soluble phosphate was obtained from soils of the phosphated plots. The indications from the work to date is that 200 to 300 pounds per acre of water extractable phosphoric acid is required in this soil to insure an adequate supply for the three crops, tomatoes, cabbage, and cucumbers. More than 300 pounds appears to be an unnecessary excess.

TABLE II—PHOSPHATE CONTENT OF SOIL, SAMPLED JUNE, 1938

Plot	Total P <sub>2</sub> O <sub>5</sub> Applied in Fertilizer (Pounds per Acre)		P <sub>2</sub> O <sub>5</sub> (Pounds Per Acre)	
	1915 to 1930	1931 to 1938	Truog Method	Water Soluble
29*	none	960	893	302
31.....	1,024	none	515	199
32*.....	none	960	721	247
33.....	none	none	447	103
34.....	1,024	1,600	1,333	481
35*.....	none	960	824	309

\*Plots 29, 32, and 35 are uniformly fertilized checks.

These preliminary findings are further evidence that the fixing power of this soil for phosphates has been saturated on these plots.

In conclusion, these results from this experiment may in part explain the success of vegetable growing in the Marietta district. It is evidently possible to maintain a peculiarly high level of available phosphate in this soil with ordinary amounts of fertilizer, and with no special emphasis upon organic matter.

## Lima Bean Production in Relation to Fertilizer Placement and Seed Spacing under Long Island Conditions

By R. H. WHITE-STEVENS, *Cornell University, Ithaca, N. Y.*, and  
J. D. HARTMAN, *Purdue University, Lafayette, Ind.*

### ABSTRACT

This material will be incorporated in a bulletin from Cornell University.

COMPARATIVE studies over a 3 year period on the Fordhook Bush Lima bean, conducted at the Long Island Vegetable Research Farm, Riverhead, New York, on the effect of fertilizer placement and spacing upon yield showed that: (a) There was no advantage from applying the fertilizer in bands on either side of the seed row, either at planting or after "come-up" over the usual broadcast application, where the same analysis and amount of fertilizer was employed throughout. (b) In 2 years out of 3, and on the average of 3 years, fertilizer applied as a band over the seed was deleterious as compared to broadcast application. (c) Yields were increased by increasing the concentration in the row of seed at planting up to two beans per 9 inches or one bean per 4½ inches which were equal in yield.

## The Interrelation of Manure, Lime, and Potash on the Growth and Maturity of the Muskmelon<sup>1</sup>

By R. L. CAROLUS and O. A. LORENZ, *Cornell University, Ithaca, N. Y.*

THE muskmelon exhibits wide differences in growth and fruitfulness as produced under the variable soil conditions existing and fertilizer practices followed in eastern New York. This paper is a report of 1 year's results of several phases of an investigation on the nutrition of the crop.<sup>2</sup>

One experiment designed to determine the effect of various rates of manure application in conjunction with various amounts of potash, was conducted on a gravelly loam soil. This field had received a heavy application of lime in 1932 which had reduced the acidity from pH 4.7 to pH 6.7 and had been in alfalfa since the lime application. The manure was applied broadcast in the fall at the rates of 0, 7.5, 15.0 and 30.0 tons per acre. In the spring a uniform application of 1,000 pounds per acre of a 5-10-0 fertilizer was applied to the entire area. In addition applications of 0, 50, 100 and 200 pounds per acre of potash as muriate of potash were applied to each of the four manure treatments. The plants were set two to a hill, the hills being 6 by 6 feet apart in 16 plots each 30 by 30 feet in size. Favorable environmental conditions following the planting on May 10 resulted in a rapid growth. The first fruits were harvested on August 1.

### EFFECT OF MANURE AND POTASH ON MATURITY AND YIELD

The pronounced decline in market price as the season advanced made it desirable to separate the early yield, harvested during the first 2 weeks, from the total yield in order to give a better economic evaluation for each treatment. The effect of treatment on rate of maturity and total yield in bushels per acre is shown in Table I. The calculated percent of the total crop reaching maturity by August 15 is shown in Table IV. The data indicate that a lack of potash depressed the early yield. During the first 2 weeks of harvest only 105 bushels were picked from the unmanured plot with no added potash while 404 bushels were harvested from the unmanured plot receiving potash at the rate of 100 pounds per acre. However, the early yield was reduced by over 100 bushels per acre when the application was increased from 100 to 200 pounds of potash per acre, although the total yield was slightly increased.

With manure applications, as low as 7.5 tons per acre, early maturity was stimulated by about the same magnitude as from an application of 100 pounds of potash. As additional nitrogen was applied to the unmanured plots to compensate for the amount contained in the 7.5 ton manure application, the influence of the manure on maturity may

<sup>1</sup>Paper No. 183, Department of Vegetable Crops, Cornell University, Ithaca, New York.

<sup>2</sup>This work is being conducted under the direction of Drs. H. C. Thompson and G. J. Raleigh.



TABLE I.—INFLUENCE OF POTASH AND MANURE ON YIELD, PROFIT AND COMPOSITION OF MUSKMELONS (VARIETY — DELICIOUS)

Manure Applications (Tons per Acre)	Early Yield*				Total Yield*				K <sub>2</sub> O in Petioles (P.p.m.)**				Net Profit Resulting from Treatment†			
	Potash Applications (Pounds per Acre)															
	0	50	100	200	0	50	100	200	0	50	100	200	0	50	100	200
0.0	105	281	404	295	534	694	723	760	150	150	175	275	0	271	415	331
7.5	442	450	413	257	761	785	849	852	150	150	150	450	474	498	510	351
15.0	432	463	303	337	743	860	809	773	150	175	575	1250	437	557	353	353
30.0	460	440	336	318	870	886	863	889	600	475	1450	2850	533	524	399	398

\*Yield expressed in 50 pound bushels per acre.

\*\*K<sub>2</sub>O, soluble in 2 per cent acetic acid, determined 1 week before the final harvest.

†Expressed in dollars per acre in excess of the amount realized from the untreated area.

have been due partly to its potash content. This would appear to be the case, for it was observed that as increased amounts of manure were applied, potash was less effective in increasing the yield.

Total yields were somewhat variable but indicated that either maximum amounts of potash or manure were effective, and also that the potash content of 30 tons of manure was adequate for the normal development of the plant under the existing conditions.

The content of soluble potash determined (1) in the petioles at the end of the season indicated that the potash content of manure was maintained in an available form; and that in addition the availability of added inorganic potash was favored by the presence of manure. The foliage of plants growing on plots receiving 30 tons of manure and on those receiving 15 tons of manure and either 100 or 200 pounds of potash remained green throughout the entire season. The leaves from the plants of the other treatments showed the usual symptoms of potash shortage to varying degrees. This marginal yellowing probably had some effect on the quality of the late maturing fruits. As leaching was not a factor during the growing season, the appearance of a potash shortage with an application of 200 pounds of inorganic potash and 7.5 tons of manure demonstrates either an extremely high potash requirement by the plant, or soil conditions that make for its rapid unavailability to the plant. The retarded absorption of potash on heavily limed soils is also indicated in the other section of the paper and has also been reported by previous investigators (2, 3).

The net profit resulting from the various treatments emphasizes the desirability of maintaining a supply of available potash in the soil that is in balance with the other nutrients and commensurate with the plants' utilization for the realization of maximum returns.

#### EFFECT OF MANURE AND LIME ON MATURITY, QUALITY, AND YIELD

A study of the influence of lime with varying quantities of manure, on the development of the melon crop was conducted on a naturally acid, pH 4.7, sandy-loam soil. Limestone was applied broadcast in the fall at the rate of 0, 1, 2 and 4 tons to the acre and manure at the rate of 0, 7.5, 15, and 30 tons to the acre at the same time on each of the

limed areas. On May 10 a uniform application of 5-10-5 fertilizer was applied at the rate of 1,000 pounds per acre to the entire area. Seed of the Bender variety was planted in hills 6 by 6 feet on the 16 plots each 30 by 30 feet in area. Moisture conditions were not as favorable and disease was more prevalent than in the other experiment. This resulted in some reduction in yield. The yields of early marketable fruits, those maturing during the first 2 weeks, total marketable yield and total unmarketable yield are shown in Table II.

TABLE II—INFLUENCE OF LIME AND MANURE ON YIELD, QUALITY AND PROFIT FROM MUSKMELONS (VARIETY — BENDER)

Manure Applications (Tons per Acre)	Early Marketable Yield*				Total Marketable Yield*				Unmarketable Yield*				Net Profit Resulting from Treatment**			
	Lime Applications (Tons per Acre)															
	0	1	2	4	0	1	2	4	0	1	2	4	0	1	2	4
0.0	38	32	119	97	288	430	423	256	162	98	88	239	0	66	114	19
7.5	187	148	196	256	433	439	423	490	175	246	238	236	152	153	169	237
15.0	158	242	336	331	284	340	503	459	246	242	157	227	56	142	273	245
30.0	214	181	287	345	263	200	325	395	293	392	333	297	78	43	168	218

\*Yield expressed in 50 pound bushels per acre.

\*\*Expressed in dollars per acre in excess of the amount realized from the untreated area

†Yield and profit from this treatment were influenced by a severe mosaic infection at midseason

Although the acidity of the soil, Table III, was reduced from pH 4.7 to pH 6.3 by an application of lime at the rate of 4 tons to the acre, even on the unlimed soils good growth resulted and the foliage of the plants appeared normal at midseason. The application of either 2 or 4 tons of limestone increased the average early yield on the manured plots by 106 bushels per acre in excess of that obtained on the unlimed areas. Limestone usually favored an increased total yield, however, on the unmanured plots the application of limestone at the 4-ton rate resulted in a lower total yield than that obtained on the unlimed plot. A study of the potash contents of the plant, Table III, suggests the

TABLE III—INFLUENCE OF LIME AND MANURE ON COMPOSITION OF MELON FOLIAGE AND REACTION OF SOIL (VARIETY — BENDER)

Manure Applications (Tons per Acre)	K <sub>2</sub> O in Petioles P.p.m.†				NO <sub>3</sub> -N in Petioles P.p.m.†				pH of Soil			
	Lime Applications (Tons per Acre)											
	0	1	2	4	0	1	2	4	0*	1*	2*	4*
0.0	1200	500	300	200	1140	2200	1180	540	4.7 4.6	4.9 4.8	5.8 5.0	6.3 5.5
7.5	3500	2200	1000	2000	340	360	340	140	4.8 5.0	5.2 5.0	5.9 5.2	6.3 6.0
15.0	4800	4000	3200	2500	520	760	810	280	4.9 4.8	5.3 4.9	6.1 5.1	6.0 6.1
30.0	8000	7500	5300	4000	780	1415	590	370	5.2 4.9	5.4 4.9	5.6 5.1	5.9 6.1

\*Upper figure represents 0 to 6 inch depth; lower figure represents 6 to 12 inch depth.

†Soluble in 2 per cent acetic acid, determined 1 week before the final harvest.

possibility that the lack of potash absorption on the heavily limed plot might offer an explanation for the reduced yield. The appearance of the characteristic marginal yellowing of the leaves, generally associated with a deficiency of potash, tended to substantiate this view. A decrease in the quantity of potash absorbed by the plant as the application of lime to the soil was increased, was observed on all manure treatments, Table III. Data from the previous experiment suggest that the high lime content of the soil, pH 6.7, was responsible for the large quantity of potash required to prevent the appearance of deficiency symptoms in the foliage.

Manure applications also hastened ripening of the fruit. On the unlimed, unmanured plot 13 per cent of the fruits matured during the first 2 weeks. With a 7.5-ton application of manure, 43 per cent ripened during the same period, and with a 30-ton application, 81 per cent matured early, Table IV. When the manure application was increased to 30 tons per acre, total yields of marketable fruits were reduced and the amounts of cull fruits were increased. This was apparently due to a pronounced acceleration in the rate of maturity. Since the vines on the plots receiving the largest manure applications showed severe wilting throughout the early maturing period, the effect might be related

TABLE IV—EFFECT OF MANURE, POTASH AND LIME ON EARLY YIELD

Manure Applications (Tons per Acre)	Variety—Delicious				Variety—Bender			
	Potash Applications (Pounds per Acre)				Lime Applications (Tons per Acre)			
	Expressed as Per Cent of Total Yield Harvested to Midseason							
	0	50	100	200	0	1	2	4
0.0	20	40	56	38	13	7	28	38
7.5	58	57	49	30	43	34	46	52
15.0	58	54	37	44	56	71	67	72
30.0	53	50	39	36	81	91	88	87

to an inadequate moisture supply and possibly would not have occurred on a heavier soil or under conditions of more favorable rainfall.

The inverse relationship, existing between the potash and  $\text{NO}_3$ -Nitrogen content of the petioles of the plants from the variously treated plots, Table III, indicated a lack of nitrogen utilization under conditions of potash shortage. The soil reactions, Table III, demonstrated the buffer action of manure; on unlimed soil it tended to lower the acidity to some extent, while on the plots receiving large lime applications it increased the acidity slightly.

Although the above presentation is based on the results and observations of a single season, the trends indicated are in such good agreement that some preliminary conclusions seem justified. On light, sandy, acid soils the addition of lime promotes early maturity and increased yields of muskmelons. The reduction in the soluble potash content which was found in plants from the limed plots, may have been due to the increase in growth that occurred or to some depressing effect of the added calcium on potassium absorption by the plant. Manure

applications also favor early maturity and increased yield of fruits. On heavily limed sandy soils, this is probably due in part to the potash content of manure which remains in readily available form.

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# The Response of Early Celery to Fertilizer Ingredients<sup>1</sup>

By F. K. CRANDALL and T. E. ODLAND, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

CELERY is a crop grown largely on the muck type of soils. Relatively little information is available concerning the growing of this crop on the mineral soils of the Northeastern States. A market garden rotation which included celery was planned and plats laid out in 1916 on a mineral type of soil at the Rhode Island Agricultural Experiment Station. In this rotation, the effects on the yields of celery of applying various amounts of manure augmented with fertilizers or growing green manure and augmenting this with fertilizers, were compared. Results obtained in this experiment were reported in 1937 (1).

In 1932 it was planned to study more in detail the effect of the major fertilizer elements nitrogen, phosphorus, and potash on the yields and quality of celery. Plats having an area of 1/63 of an acre were laid out only a short distance from the previously mentioned experiment. A 2-year rotation was planned where the celery crop of 1 year was followed by tomatoes during the next season. A sufficient number of plats was used to make it possible to grow a crop of celery each year. Winter rye was sown after the crop of celery and tomatoes had been harvested. This green manure was allowed to grow in the spring until the early part of May before it was plowed down. Manure was applied uniformly to the plats at the rate of 8 tons per acre. This was a small application but previous results had shown a significant increase in yields of celery on nearby plats where this small amount had been broadcasted.

Hydrated lime was applied in 1915, and limestone in 1918 and 1920, to the area later selected for this experiment. A pH determination made in 1933, the year the experiment was actually started, showed a near neutral condition. The standard fertilizer used on the check plats approximated a 6-8-6 grade. This was applied at the rate of 1,500 pounds per acre per year the first 3 years of the test and at the rate of 2,000 pounds in 1936, 1937, and 1938. Fertilizers having levels of nitrogen, phosphorus, and potash 50 per cent below and above the standard fertilizer were included. All treatments were in triplicate excepting the standard or check which was in quadruplicate. The average yields obtained over the 6-year period, are presented in Table I.

## NITROGEN RESPONSE

Table I shows that decreasing the nitrogen 50 per cent reduced the trimmed weight, number of bunches, and average weight of bunches more than a similar reduction in the phosphorus and potash content of the fertilizer. The statistical analyses of the yields indicate that the reduction was significant. An increase of 50 per cent in the nitrogen

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content of the fertilizer consistently increased weight, number of bunches, and average weight of bunches over yields obtained on the check plots. The increase in yield with the increased nitrogen application was not as large as the decrease, as might be expected, but in view of the fact that yields were consistently higher with the three levels of nitrogen, it must be concluded that nitrogen is an important element in the growing of celery. Results secured in other tests indicate that this conclusion is justified for a number of the common vegetable crops under conditions which prevail at this station. As might be expected there are some exceptions to this conclusion.

TABLE I—AVERAGE YIELDS OF NO. 1 CELERY IN HUNDRED-WEIGHT AND DOZEN BUNCHES PER ACRE IN A FERTILIZER RATIO EXPERIMENT (1933-38)

Fertilizer Treatment	Fertilizer Grade	Trimmed Weight (Cwt)	Dozen Bunches	Difference	Average Weight
					No. 1 Bunches (Pounds)
Standard ..	6-8-6	221.4	1073	—	1.72
Low nitrogen	3-8-6	206.0	1012	-61*	1.70
High nitrogen	9-8-6	231.2	1106	+33	1.74
Low phosphorus	6-4-6	211.6	1034	-39	1.71
High phosphorus	6-12-6	229.9	1081	+8	1.74
Low potash	6-8-3	213.3	1038	-35	1.71
High potash	6-8-9	244.7	1159	+86*	1.76

\*A significant difference by statistical analysis.

### PHOSPHORUS RESPONSE

Of the three fertilizer elements compared, phosphorus affected the yields of celery the least. A hasty glance at the table of yields would not seem to substantiate this fact as the untrimmed weight and dozen bunches harvested were smaller where the low phosphorus fertilizer was applied than where the low potash fertilizer was used. However, the yields obtained where these low phosphorus and low potash fertilizers were applied were but little different, while the increase in yield where extra phosphorus was applied was much smaller than with either extra nitrogen or potash, which is the basis for the deduction. This we have found to be generally true regarding phosphorus in our fertilizer studies. However, there are occasional exceptions with several of the vegetable crops and an occasional crop which responds to this element.

### POTASH RESPONSE

The highest average yield was obtained where the extra potash fertilizer was applied. This was true alike for trimmed weight, dozen bunches, and average weight per bunch. Reducing the potash content of the fertilizer 50 per cent did not reduce yields as much as a like reduction in the nitrogen content. This may be explained, in part at least, by the fact that potash as applied in fertilizers, is held longer in the soil than nitrogen. Fertilizer used for growing celery in the muck areas contains a much higher proportion of potash than did the fertilizers used in this test. A grade, such as a 3-12-15, which contains as many units of potash as units of nitrogen and phosphoric acid combined

is not considered out of proportion as regards potash for muck soils. In the experiment under consideration the fertilizer which contained 50 per cent more potash than the standard 6-8-6 was approximately a 6-8-9, containing 9 units of potash to a total of 14 of nitrogen and phosphoric acid.

Previous results at this station have shown that yields of celery can be increased by applying more potash than many of our grades of fertilizer contain. The data secured in this experiment substantiate previous findings and emphasize the importance of potash in celery growing.

#### EFFECT OF FERTILIZERS ON QUALITY

Quality is a difficult thing to define or determine. In celery, crispness and stringiness were assumed as factors closely associated with quality. Breaking, cutting, and tasting tests were attempted. These tests did not indicate any measurable differences due to treatment, though relatively little time was given to this phase of the experiment and the equipment used was crude.

#### SUMMARY

Celery was grown on a mineral type of soil with a small application of stable manure augmented by a green manure crop and fertilizers with varying proportions of nitrogen, phosphorus, and potash.

Yields were significantly reduced where the nitrogen content of the standard 6-8-6 fertilizer was reduced 50 per cent. Where the nitrogen was increased to 50 per cent above the level of the standard fertilizer, the average yield obtained was increased 33 dozen bunches per acre. Phosphorus did not affect yields as much as nitrogen and potash. A small decrease in yield resulted, however, from reducing the phosphorus content of the standard fertilizer one-half. Increasing the potash content of the fertilizer 50 per cent resulted in an increase of 86 dozen bunches in the average yield. Decreasing the potash did not reduce the average yield as much as decreasing the nitrogen.

The quality factors, crispness and stringiness, did not seem to be affected by the variations in nitrogen, phosphorus, and potash supplied in the fertilizers.

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# Influence of Lime and Calcium Chloride Applications on Growth and Yield of Sweetpotatoes

By C. E. STEINBAUER and J. H. BEATTIE, *U. S. Horticultural Station, Beltsville, Md.*

**T**HERE is but little experimental evidence in the literature concerning the effects of liming and soil acidity on the growth and performance of the sweetpotato. The use of lime on very acid soils has been mentioned as favorable to the crop by several writers but apparently most such statements have been backed by little, if any, quantitative data. Geise (1) has published data showing decided benefits from liming a very acid soil.

In 1933 a field assigned for sweet potato investigations at the United States Horticultural Station was found to have a soil pH range of 4.6 to 5.0. An experiment was planned to determine what effect changes in soil reaction resulting from liming would have on color, yield, and other characters of the sweetpotato. In order to ascertain whether any differences found on limed plots could be considered due to reductions in acidity and not due to the calcium supplied by the lime, calcium chloride was applied to certain plots at such rates as to supply approximately the same amounts of calcium as were added by the lime treatments.

## EXPERIMENTAL PROCEDURE

Two varieties of sweet potatoes, one a moist-fleshed, the other a dry-fleshed type, were grown in ridge culture in this study each year: Porto Rico and Yellow Jersey in 1933; Porto Rico and Vineland Bush during the years 1934 to 1937 inclusive. All plantings were made with draws or sprouts of approximately equal size. The Porto Rico was planted in a fairly uniform-appearing Sassafras sandy loam soil, and Yellow Jersey and Vineland Bush were planted on an adjacent area having a slightly heavier soil.

The experimental area for each variety was laid out five plots wide by five plots long with the treated plots systematically replicated within the area. Each individual plot consisted of five parallel 30-foot rows spaced 4 feet apart. Records were taken only on the inner three of each five rows; the outer two were used as guard rows. Alleys 4 feet wide were left between the ends of the plots. A uniform broadcast fertilization of the whole experimental area was made each year before planting and before treatments were applied. This consisted of 1,000 pounds per acre of 0-8-8 in 1933, 5-10-5 in 1934, 5-8-5 in 1935 and in 1936, and 5-8-9 in 1937. In addition a rye cover crop planted each year after the crop was harvested was plowed under the following spring.

Hydrated lime and calcium chloride in the required amounts were applied broadcast within 2 weeks after planting (care being taken not to touch the plants), except in 1933 when the applications were made in furrows under the rows 2 days prior to planting. Treatments used each year were as follows: (a) low lime, 500 pounds hydrated lime



per acre; (b) high lime, 2,000 pounds hydrated lime per acre; (c) low calcium chloride, 250 pounds per acre; (d) high calcium chloride, 1,000 pounds per acre; (e) control, untreated. The locations of the plots remained the same from year to year, hence any unused residue remaining in the soil from the preceding year or years supplemented that applied during any current year.

At the beginning of the 1936 season tests indicated that the acidity of the control plots throughout the experimental area had decreased somewhat since the start of the experiment in 1933. It was considered desirable to keep the acidity of the control or reference plots fairly high, therefore a uniform "blanket" application of 325-mesh sulphur at 400 pounds per acre was made over the entire experimental area at the time the lime and calcium chloride applications for 1936 were made.

At intervals of 3 to 4 weeks during the seasons of 1936 and 1937 hydrogen-ion determinations were made electrometrically using a quinhydrone electrode on composite soil samples taken from the surface 6 inches of each plot.

At harvest each year the crop was graded into jumbo or oversize roots, U. S. No. 1 and U. S. No. 2 grades. The roots in each grade were weighed and the No. 1 roots from each plot stored separately in an artificially heated storage house.

Yield data for the individual years and for the 4-year period 1934 to 1937 were analyzed by the Analysis of Variance (3). The Analysis of Variance was also applied to the soil pH data.<sup>1</sup> The authors have never seen any report in the literature on the application of this method to pH data hence a brief note may serve to assist others in making this type of analysis. Inasmuch as pH values are logarithmic functions they cannot be subjected to statistical treatment as measures of acidity. The pH values are therefore converted to their corresponding Ch values. These values are then coded, by multiplying by a factor (say 1,000 or 10,000) suitable to the Ch range studied, to avoid unnecessarily large numbers of digits in the sums and sums of squares accumulated in the analysis. By working from an assumed mean near the middle of the range studied the size of the numbers worked with can be still further reduced. It is convenient to use a whole-number pH value (such as 5.0 or 6.0) as the assumed mean since the corresponding Ch value is then always the figure 1 preceded by the appropriate number of ciphers, an easily subtracted quantity. In picking up the sums of squares it is convenient to work from a frequency table and a previously prepared table of squared coded deviation values. This obviates the necessity of setting up all the relatively large coded Ch numbers in a table and reduces the large amount of work required if each item were squared separately. In interpreting results with a set of pH data, it is necessary to remember that determinations of the significance of differences between means of treatments with respect to error are made on a Ch basis. On a pH basis relatively large differences in the direction of higher pH values may be statistically insignificant in some cases whereas much smaller differences in the direction of lower pH values

<sup>1</sup>Thanks are due V. R. Boswell for pertinent suggestions on the application of the Analysis of Variance to the pH data.

may be highly significant. This follows from the logarithmic nature of the pH unit.

TABLE I—SOIL ACIDITY OF SWEETPOTATO PLOTS TREATED WITH LIME AND CALCIUM CHLORIDE (AVERAGE ACIDITY OF QUINTUPLICATE PLOTS)

Treatment	Date of Determination							Mean Acidity for all Dates	
	Aug- ust 4, 1936 (pH)	Sep- tember 2, 1936 (pH)	Oct- ber 6, 1936 (pH)	June 9, 1937 (pH)	July 26, 1937 (pH)	Aug- ust 28, 1937 (pH)	Sep- tember 30, 1937 (pH)	as pH	as Ch*
<i>Porto Rico Area</i>									
1. Lime 500 pounds per acre.	5.62	5.98	5.87	5.47	6.11	6.48	6.08	5.81	.0155
2. Lime 2000 pounds per acre	6.86	7.06	7.14	6.83	7.09	7.74	7.39	7.08	.0008
3. Calcium chloride 250 pounds per acre	4.74	5.13	5.03	5.16	4.47	5.38	5.39	4.96	.1100
4. Calcium chloride 1000 pounds per acre	4.81	5.48	4.97	4.87	4.60	5.34	5.22	4.95	.1120
5. Control	5.11	5.45	5.03	5.01	4.93	5.25	5.08	5.14	.0717
Minimum Ch difference required for significance between means of treatments: .0331.* Statistically significant differences between means of treatments (as Ch): 1,2,5 <3,4; 1,2 <5.									
<i>Vineland Bush Area</i>									
1. Lime 500 pounds per acre.	5.89	6.26	5.99	5.48	5.84	6.31	6.14	5.89	.0126
2. Lime 2000 pounds per acre	7.10	7.23	7.40	6.69	7.45	7.74	7.39	7.13	.0007
3. Calcium chloride 250 pounds per acre	4.05	5.24	4.34	4.86	4.61	5.23	5.09	4.74	.1790
4. Calcium chloride 1000 pounds per acre	4.34	5.09	4.85	4.62	4.49	4.97	4.97	4.68	.2060
5. Control	4.85	5.30	5.00	5.11	4.94	5.58	5.48	5.11	.0774
Minimum Ch difference required for significance between means of treatments: .0849.* Statistically significant differences between means of treatments (as Ch): 1,2,5 <3,4.									
<i>Combined Data for Both Areas</i>									
1. Lime 500 pounds per acre.	5.73	6.10	5.92	5.47	5.95	6.38	6.10	5.85	.0141
2. Lime 2000 pounds per acre	6.96	7.13	7.25	6.75	7.23	7.74	7.39	7.10	.0008
3. Calcium chloride 250 pounds per acre	4.69	5.18	4.56	4.98	4.53	5.29	5.21	4.84	.1440
4. Calcium chloride 1000 pounds per acre	4.52	5.24	4.90	4.72	4.54	5.11	5.08	4.79	.1590
5. Control	4.95	5.36	5.02	5.05	4.93	5.38	5.23	5.12	.0746
Minimum Ch difference required for significance between means of treatments: .0456.* Statistically significant differences between means of treatments (as Ch): 1,2,5 <3,4; 1,2 <5.									

\*Normality  $\times 10,000$

## RESULTS

*Soil Reaction:*—In Table I data are presented showing the mean pH values for each treatment on various dates during the 1936 and 1937 seasons for the two experimental areas separately and for the two tests combined. Variance analysis of these data showed highly significant variance due to treatments with reference to residual error, to the interaction between treatments and dates, and to the interaction between treatments and areas. Variance due to dates was highly significant when referred to residual error and was also significant when referred to the interaction between treatments and dates. These results indicate that the soil acidity varied with the date of determination and with the area on which the experiment was conducted, but that regardless of the date of determination or of the experimental area utilized, the treatments caused significant variations in soil acidity.

Both the low and high lime treatments noticeably decreased soil acidity; the high lime treatment actually made the soil alkaline on many of the plots. Calcium chloride applications, on the other hand, tended to increase acidity, particularly on the heavier soil (Vineland Bush area).

*Color and Quality*.—At harvest and at various times during the storage periods samples of about 10 roots each selected from each treatment for uniformity of size were compared visually as to skin and flesh color. Although there were slight variations in both skin and flesh color in all lots examined, no consistent color differences were observed between treatments. A few color comparisons were also made on the flesh of baked roots from the various treatments. In one test on the variety Porto Rico in the fall of 1936 flesh colors and textures of baked roots from the lime and calcium chloride treated plots were indistinguishable. Roots of the control treatment in this test appeared to be a little softer and of a slightly deeper shade of yellow than those from the lime or calcium chloride treated plots. No differences as to texture or color were observed with the variety Vineland Bush. In other tests conducted during the summer of 1938 on roots of the two varieties which had been in storage for approximately 9 months, no consistent differences as to flesh color or texture were found.

*Yields*.—Mean yields of sweetpotatoes for the various treatments, in pounds per plot are given in Table II. Statistically significant differences between treatments are indicated. Twice the standard error of the difference is considered the minimum level for significance of differences between means of treatments. The grade "No. 1 and larger" includes the jumbo and No. 1 grades (jumbo or oversize potatoes were found only in 1935 and 1937 with the variety Porto Rico). In order to simplify the table, data for the No. 2 grade are omitted, but can be easily calculated as the difference between total yields and No. 1 and larger (or No. 1). In 1933, a severe drouth caused the sweetpotato crop to be practically a failure. This is apparent in the yield data for that season. Rainfall was also poorly distributed in 1937 resulting in somewhat reduced yields on all plots in the experiment.

Only in the 1935 and 1937 seasons and the 4-year period 1934 to 1937 with the variety Porto Rico were there significant variances in yield due to treatment, when referred to the residual error. No significant variances in actual or percentage yields due to treatment were found with the Yellow Jersey or Vineland Bush varieties in any year or grade studied, or over the experimental period as a whole. Analysis of the combined data for the two tests (varieties) in the individual years 4-year period were variances due to treatments significant.

In comparing the results on limed plots with those of the untreated controls, in only a single case was there a statistically significant difference in yield, that of Porto Rico "No. 1 and larger" roots from the high lime treatment in 1935 was lower than that of the control. In 1937, the only other year in which jumbo or oversize roots were developed, the yield on the high lime treated plots was not significantly different from that of the control treatment. Most of the differences between the high lime and control treatments show no statistical signi-

TABLE II—EFFECT OF ANNUAL APPLICATIONS OF LIME OR CALCIUM CHLORIDE ON MEAN YIELDS PER PLOT (POUNDS) OF THREE VARIETIES OF SWEETPOTATOES (QUINTUPPLICATE PLOTS)

Treatment	Year									
	1933		1934		1935		1936		1937	
	No. 1	Total	No. 1	Total	No. 1 and Larger	No. 1	Total	No. 1 and Larger	No. 1	Total
<i>Variety Porto Rico</i>										
1. Lime 500 pounds per acre	21.4	32.6	89.8	111.8	81.1	72.6	110.2	75.4	102.0	29.5
2. Lime 2000 pounds per acre	22.7	35.5	82.6	103.2	50.1	47.1	82.1	74.6	102.4	38.4
3. Calcium chloride 250 pounds per acre	27.2	40.6	85.4	107.2	82.9	81.1	112.9	83.0	106.0	34.3
4. Calcium chloride 1000 pounds per acre	26.1	36.9	97.8	115.5	79.3	71.1	105.8	101.4	132.4	48.5
5. Control	20.0	34.0	85.5	105.5	69.5	64.7	95.9	78.8	102.2	34.0
Minimum difference required for significance between means of treatments					19.2	19.0	19.7			7.0
Statistically significant differences					2 < 1,3,4,5	2 < 1,3,4	2 < 1,3,4	4 > 1,2,3,5	2 > 1,3,5	4 > 1,2,3,5
<i>Variety Vineland Bush (1934 Through 1937)</i>										
1. Lime 500 pounds per acre	51.8	72.5	97.0	128.1	—*	40.5	101.5	143.2	203.4	—*
2. Lime 2000 pounds per acre	44.5	66.7	90.9	122.7	—	45.4	97.3	126.0	182.8	—
3. Calcium chloride 250 pounds per acre	45.2	66.9	93.4	124.9	—	47.9	101.5	161.4	225.4	—
4. Calcium chloride 1000 pounds per acre	31.3	51.3	100.4	136.2	—	42.5	93.7	140.8	197.0	—
5. Control	46.4	69.6	90.4	122.3	—	46.6	103.1	139.0	195.6	—
<i>Two Tests (Varieties) Combined</i>										
1. Lime 500 pounds per acre	36.6	52.5	93.4	120.0	60.8	56.6	105.9	109.3	152.8	33.6
2. Lime 2000 pounds per acre	33.6	51.1	86.8	113.0	47.8	46.3	89.7	100.3	142.6	38.1
3. Calcium chloride 250 pounds per acre	36.2	53.8	89.4	116.1	65.4	64.5	107.2	122.2	165.7	41.7
4. Calcium chloride 1000 pounds per acre	28.7	44.1	99.1	125.9	60.9	56.8	99.8	121.1	164.7	45.9
5. Control	33.2	51.8	88.0	113.9	58.1	55.7	99.5	108.9	148.9	36.8
Minimum difference required for significance between means of treatments										6.2
Statistically significant differences								3 > 1	3 > 1	4 > 1,2,5
<i>Variety Jersey Yellow (1933)</i>										
1. Lime 500 pounds per acre	51.8	72.5	97.0	128.1	—*	40.5	101.5	143.2	203.4	—*
2. Lime 2000 pounds per acre	44.5	66.7	90.9	122.7	—	45.4	97.3	126.0	182.8	—
3. Calcium chloride 250 pounds per acre	45.2	66.9	93.4	124.9	—	47.9	101.5	161.4	225.4	—
4. Calcium chloride 1000 pounds per acre	31.3	51.3	100.4	136.2	—	42.5	93.7	140.8	197.0	—
5. Control	46.4	69.6	90.4	122.3	—	46.6	103.1	139.0	195.6	—
1. Lime 500 pounds per acre	66.3	91.7	69.0	91.7	66.3	91.7	69.0	66.3	91.7	66.3
2. Lime 2000 pounds per acre	60.2	85.1	61.4	85.1	60.2	85.1	61.4	60.2	85.1	60.2
3. Calcium chloride 250 pounds per acre	70.5	92.8	71.4	92.8	70.5	92.8	71.4	70.5	92.8	70.5
4. Calcium chloride 1000 pounds per acre	76.2	103.1	81.8	103.1	76.2	103.1	81.8	76.2	103.1	76.2
5. Control	64.5	87.5	66.9	87.5	64.5	87.5	66.9	64.5	87.5	64.5
Minimum difference required for significance between means of treatments										
Statistically significant differences										
<i>Two Tests (Varieties) Combined</i>										
1. Lime 500 pounds per acre	66.3	91.7	69.0	91.7	66.3	91.7	69.0	66.3	91.7	66.3
2. Lime 2000 pounds per acre	60.2	85.1	61.4	85.1	60.2	85.1	61.4	60.2	85.1	60.2
3. Calcium chloride 250 pounds per acre	70.5	92.8	71.4	92.8	70.5	92.8	71.4	70.5	92.8	70.5
4. Calcium chloride 1000 pounds per acre	76.2	103.1	81.8	103.1	76.2	103.1	81.8	76.2	103.1	76.2
5. Control	64.5	87.5	66.9	87.5	64.5	87.5	66.9	64.5	87.5	64.5
Minimum difference required for significance between means of treatments										
Statistically significant differences										
<i>Two Tests (Varieties) Combined</i>										
1. Lime 500 pounds per acre	66.3	91.7	69.0	91.7	66.3	91.7	69.0	66.3	91.7	66.3
2. Lime 2000 pounds per acre	60.2	85.1	61.4	85.1	60.2	85.1	61.4	60.2	85.1	60.2
3. Calcium chloride 250 pounds per acre	70.5	92.8	71.4	92.8	70.5	92.8	71.4	70.5	92.8	70.5
4. Calcium chloride 1000 pounds per acre	76.2	103.1	81.8	103.1	76.2	103.1	81.8	76.2	103.1	76.2
5. Control	64.5	87.5	66.9	87.5	64.5	87.5	66.9	64.5	87.5	64.5
Minimum difference required for significance between means of treatments										
Statistically significant differences										

\*Data same as for "No. 1".

ficance. Nevertheless, the yield of No. 1 potatoes and total yield were generally lower with the high lime than with the control treatment, suggesting a yield depressing influence of heavy lime applications. During the last 2 years of the experiment a marked retarding of vine growth and bronzing of the foliage on the Porto Rico plants was observed on the high lime plots during the first 6 to 8 weeks of growth in each season. This condition was not evident during the latter portions of the growing seasons. This retardation of vine growth was not apparent with the low lime treatment in Porto Rico or with either the high or low lime treatments on the Vineland Bush variety.

Differences in yields between the low calcium chloride treated plots and the control plots were not statistically significant in any case. However, examination of the data in Table II shows that in general the mean yields of the No. 1 grade roots (and No. 1 and larger also) tended to be higher with the low chloride treated plots than were those of the controls. With a few exceptions this was also true with regard to total yields per plot.

Differences favoring the high chloride plots over the controls are observed in Table II, some of which are statistically significant. With the high chloride treatment there was a noticeable tendency for production of more of the larger size potatoes, accompanied by a corresponding tendency for decreases in the weight and percentage of No. 2 grade potatoes. From the data at hand it cannot be positively stated that the production of larger size roots as a result of chloride applications was due entirely to the effects of the chloride ion since soil acidity was affected at the same time as the chloride ion was supplied. In the light of experiments reported by Geise (1), however, it would seem that increased acidity should decrease rather than increase yields, hence the indication that the chloride ion aids production of large size roots may have some justification. From a practical standpoint applications of calcium chloride will not be feasible unless a cheap source of chloride is available or unless the crop can command a relatively high price. Assuming the 4-year Porto Rico results as average, the increased yield of No. 1 grade potatoes from heavy calcium chloride application was about 22 bushels per acre and the increased yield of No. 1 and larger roots about 30 bushels per acre. Benefits from the use of sodium chloride on sweetpotatoes have been reported by Johnson, Zimmerman, and Geise (2).

#### CONCLUSIONS

Under conditions such as obtained during this study as many as five heavy annual applications of lime to a soil which was originally quite acid may not significantly change the color, or edible quality, but may slightly reduce yields of sweetpotatoes. The soil reaction may be markedly altered by such treatment. There is some indication from the results obtained that heavy applications of calcium chloride under the same conditions may increase the total yield and the proportion of large size sweetpotatoes in certain varieties, without altering root color or edible quality.

These results confirm the suggestions of other workers that sweetpotatoes are not very exacting with respect to soil acidity. Apparently

sweetpotatoes do best in a slightly to moderately acid soil, and yields may be somewhat decreased when the soil becomes neutral or alkaline in reaction.

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# The Effect of Fertilizer Placement, as Influenced by Soil Moisture, on Seed Germination

By M. M. PARKER and R. C. OLIVER, *Virginia Truck Experiment Station, Norfolk, Va.*

THE necessity for using large amounts of plant nutrients in the form of commercial fertilizers for vegetable crops has brought about problems of application that frequently are not properly evaluated chiefly because of the insidious nature of fertilizer toxicity. The damage may take the form of a reduction in germination or a temporary lull in growth shortly after the seedlings emerge, particularly if the fertilizer was used at or just prior to planting the seed. The variability in the amount of injury associated with any specific placement in different fields the same year and in the same field over a period of years led to an experiment designed to determine the part that environmental conditions play in influencing the effectiveness of several methods of fertilizer application.

## METHODS

Covered greenhouse benches were so arranged that different degrees of soil moisture could be maintained. The benches were filled to a depth of 7 inches with a soil classified as a Norfolk coarse sandy loam with a very low moisture holding capacity of 32 per cent. One series was kept just wet enough to insure germination of the seed. It contained 7.63 per cent moisture on the dry soil basis when the seed was planted and 5.37 per cent at the completion of germination. A second series was held at what would be considered optimum moisture for the soil under consideration, 8.80 per cent at the start and 6.84 at the end of germination. A third series was kept wet 9.48 per cent to 7.84 per cent. The covers were objectionable in that a moist atmosphere prevailed even over the soils that were kept in a dry state, which probably favorably influenced germination to some extent.

Counted seed of snap beans, peas and cabbage were planted in rows the same day the fertilizer was applied. Three placements of a 6-6-5 mixture were used at the rate of a thousand pounds to the acre based on rows 30 inches apart. Cal-nitro, nitrate of soda, sulphate of ammonia, superphosphate and muriate of potash composed the mixture. The fertilizers that were mixed with the soil were applied in a strip 14 inches wide and incorporated uniformly into the soil to a depth of several inches. Sideplaced fertilizers were placed in bands 2 inches wide, 2 inches to the sides of the seed and 2 inches below seed level. The third placement was in a band 2 inches wide and 2 inches directly beneath the seed level. The moisture readings of the soil to a depth of 2 inches were obtained each day from the time of planting the seed until germination was complete.

## RESULTS

The germination data obtained at the three levels of moisture with the different placements is shown graphically in Figs. 1, 2, and 3. Fertilizers mixed with the soil immediately before planting proved

decidedly injurious to germination when just sufficient moisture was present to bring up the seed. Cabbage was the least injured of the three crops. Its germination was 50 per cent as great as that of the unfertilized lot in the compartment with the lowest moisture content. The germination of the peas was reduced to approximately 40 per cent and snap beans to 35 per cent of that of the unfertilized check. Fertilizers were less injurious when placed in a band 2 inches beneath the seed than when they were mixed with the soil, except in the case of snap beans, but the former position frequently brings about losses later, after the roots emerge through the zone of fertilizer free soil and contact the fertilizer. The only placement of the fertilizer in the dry soil that had little adverse effect on germination was the side placement 2 inches to the sides of the seed and 2 inches below seed level. This treatment

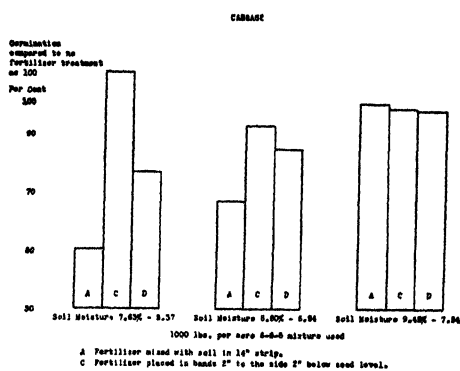


FIG. 1. Percentage germination of cabbage seed in soils of three degrees of moisture with fertilizers placed in three positions relative to the location of the seed.

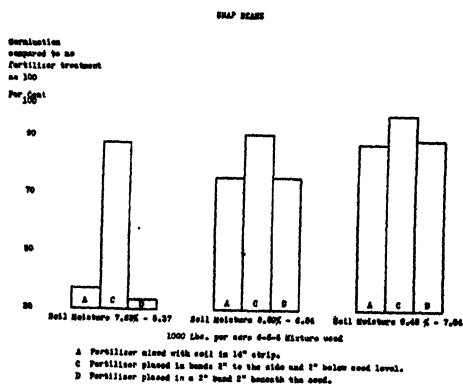


FIG. 2. Percentage germination of snap bean seeds in soils of three degrees of moisture with fertilizers placed in three positions relative to the location of the seed.

resulted in only a 12 per cent reduction with peas below that obtained from the unfertilized check; a 14 per cent reduction with the snap beans and with cabbage a germination better than that of the check. Increasing the soil moisture up to 8.80 per cent which was nearer the ideal for germination in this particular soil brought about a sharp decrease in the injuries resulting from fertilizers mixed with the soil, and placed directly beneath the seed, but fertilizers mixed with the soil again were more injurious than those placed beneath the seed. Where the fertilizer was mixed with the soil the germination of the cabbage and peas was about 18 per cent better, and that of the snap beans 40 per cent greater compared to that obtained on the drier soil. Fertilizer placed beneath the seed compared to the same placement in the drier soil showed an improvement in seed germination of 8 per cent for cabbage,



none for the peas and 40 per cent for the snap beans. Side placed fertilizers had almost no deleterious effect. Cabbage germinated 92 per cent compared to the check lot as 100, peas 86 per cent and snap beans 90 per cent.

The highest moisture content at which the soil was held, 9.48 per cent, tended to eliminate much of the injury due to the location of the fertilizer. The per cent germination with cabbage was about equal for the three placements; with snap beans it was slightly higher with the side placement, and with peas the injury was only severe when the fertilizer was mixed with the soil.

### SALT CONCENTRATIONS

Comparative salt concentrations readings<sup>1</sup> were made of the soil in the compartments held at the lowest moisture level to determine the relationship between the soluble salt concentration near the seed and the injury to germination. The samples were taken to a depth of 2 inches and as near as possible to the row of seeds during the period of germination.

The soluble salt concentration of the soil was determined by the electrical conductivity method. Readings were made on a 1:12 soil-water suspension. The apparatus used was similar to that described by Puri and Anand (1).

The readings were 1,700 ohms resistance in the samples taken where the fertilizer was mixed with the soil, 3,800 ohms where it was placed in a band directly beneath the seed, and 4,600 ohms where bands were placed on each side of the seed. The reading for the untreated soil was 6,700 ohms.

Since a low resistance indicates a high soluble salt concentration it is evident that the severity of injury was directly associated with the relative soluble salt concentration near the seed.

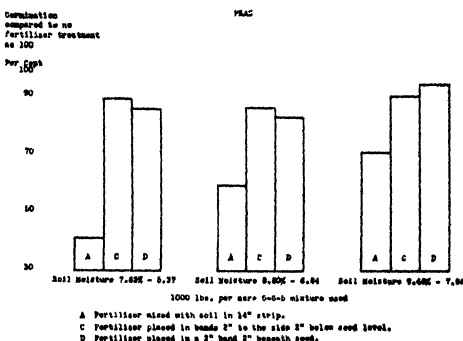


FIG. 3. Percentage germination of pea seeds in soils of three degrees of moisture with fertilizers placed in three positions relative to the location of the seed.

### CONCLUSION

The amount of injury that takes place when fertilizers are mixed with the soil or placed in a band beneath the seed is primarily dependent upon the concentration of the fertilizer salts which in turn is partly dependent upon the soil moisture. Fertilizers mixed with the soil were initially more injurious to germinating seed than fertilizers placed in a band 2 inches beneath the seed in soils with a relatively low moisture

<sup>1</sup>Acknowledgment is made to Dr. E. R. Purvis and George Higson of the Soils Department for making the concentration readings.

content. Fertilizers placed 2 inches away from and 2 inches below the level of the seed were relatively non-injurious irrespective of soil moisture content. Fertilizers mixed with the soil produced the highest soluble salt concentration in the vicinity of the germinating seed. The next highest concentration was from the fertilizer placed in a band beneath the seed. Side placement gave a lower concentration of salt near the seed, but slightly higher than that of the unfertilized check.

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# Carbohydrate Metabolism in Relation to Boron Nutrition<sup>1</sup>

By R. H. WHITE-STEVENSON, *Cornell University, Ithaca, N. Y.*

**B**ORON deficiency has been reported upon 46 crops and in 14 different countries to date. The interest in the problem can be gathered from the fact that over 400 papers on the subject have been published since January 1936.

In spite of the immense flood of literature on boron nutrition, comparatively few efforts have been made to draw the salient findings of the numerous investigators into a general schematic explanation of the relation between the external visible characteristics of boron malnutrition, which are surprisingly similar for a wide variety of crop plants, and the internal physiological function therewith associated.

The excellent reviews by Dennis and O'Brien (16), Dennis (63), and Greenhill (21), discuss the major practical field aspects and to an extent consider the function of boron in the plant. This paper, however, is designed to draw from the miscellaneous work of other investigators a tentative explanation of the relation of boron deficiency to carbohydrate metabolism in its expression of external symptoms and internal physiology, and to supplement such suggestions with preliminary data obtained from experiments on the subject with four vegetable crop plants.

Because of the necessity for brevity reference to literature will be made by a general summarized statement followed by the respective listed authorities by number for bibliographical citation in the printed text only.

## RELATION OF BORON DEFICIENCY TO EXTERNAL SYMPTOMS

In general inadequate boron nutrition affects the plant mainly in the following regions in the following manner:

(a) A cessation of meristematic activity in part or all of the tissues thus engaged, apparently depending upon the suddenness or severity of the deficiency. This ultimately manifests itself as death and decay of the apical meristem, lateral buds, cambium layers and root tips (5, 9, 10, 16, 18, 19, 23, 24, 26, 32, 33, 40, 41, 42, 44, 54, 55, 57, 58, 59).

(b) The vascular tissue becomes impaired in its functional activity, the phloem becoming disorganized and hypertrophied. In general this condition is confined to the phloem and medullary tissue, leaving the xylem apparently intact. Although weakened cambial activity following the initiation of inferior boron nutrition may, in some cases, result in the formation of abnormal and apparently non-functional xylem strands (10, 11, 19, 23, 24, 26, 32, 33, 34, 45, 54, 57, 58).

(c) Foliage degeneration is usually effected upon the younger leaves first, which show abnormalities accruing from disorganized meristematic activity. Older leaves appear to follow other parts of the plant

<sup>1</sup>Paper No. 186, Department of Vegetable Crops, Cornell University, Ithaca, New York.

in showing necrotic development, excess anthocyanin formation, and a distinct turgidity and leatheriness, resulting in extreme brittleness (14, 17, 18, 19, 21, 23, 24, 29, 32, 34, 37, 40, 41, 42, 50, 57, 58, 60).

(d) The roots owing to dying back of the tips tend to undergo an excessive branching and ramification only in turn to cease active growth (24, 32, 34, 53, 57, 58). Storage roots, and tubers, fail to enlarge normally develop center rot, surface lesions and ultimately become ready seats of infection for numerous secondary facultative saprophytes, which soon develop into active parasites and effect the complete degeneration of the storage region in certain severe cases (1, 2, 5, 6, 7, 14, 15, 17, 21, 22, 25, 27, 28, 29, 30, 36, 44, 46, 47, 53, 54, 63).

(e) Fruits and fruiting tissues follow a similar decadence cessation of growth, internal and peripheral decay and either drop prematurely or rot *in situ* (32, 33, 34, 60).

This composite summary of external symptoms of boron deficiency is not necessarily found in its entirety upon any one crop under any one set of conditions. It is essentially the *ne plus ultra* of a severe boron deficiency.

#### RELATION OF BORON DEFICIENCY TO INTERNAL PHYSIOLOGY

It is fairly certain that this picture of the injurious effects of boron deficiency cannot be ascribed solely to lack of boron in the affected regions (8, 9). There is some evidence that boron is evenly distributed throughout the plant with little or no accumulation in specific regions (39), and that when a continuous stream of boron fails to enter the plant, boron present in old leaves is not retranslocated to the young growing tips (8, 9). These however, do continue to grow with an ever decreasing activity, and this decadence seems to follow certain fundamental changes in the physiology of the entire plant (23, 24, 32, 33, 34, 35, 37, 57, 58).

The evidence now available appears to point to a disruption in the food conducting cells of the vascular tissue as being the initial physiological disorder to occur (8, 9, 10, 11, 18, 23, 24, 32, 33, 34, 45, 49, 50, 51, 54, 57, 58).

This disruption of phloem tissue results in a marked interruption of the movement of soil nutrients to the upper parts of the plant, and an interruption of carbohydrate transfer from the regions of manufacture, the older leaves, to the rest of the plant in general (23, 24, 29, 31, 32, 33, 34, 35, 43). As a result of this the following physiological disorders may be considered to arise in the various parts of the plant as previously listed.

(a) The meristematic regions cease to continue mitotic division and incompletely formed cells are produced. Due to an incomplete food supply these cells become affected and die. This condition tends to prevail wherever meristematic activity normally occurs; in apical and lateral stem points, vascular cambium and in root tips (8, 9, 10, 18, 23, 24, 29, 32, 33, 34, 40, 41, 42, 44, 45, 49, 50, 53, 54, 57, 58).

In some cases where boron deficiency is induced gradually the meristematic regions are depressed only in parts, resulting in deformed

growth due to unilateral or uniaxial cell division (14, 29, 32, 33, 34, 41, 42).

(b) The roots show an inability to function as absorbing organs and boron deficiency frequently results in many other mineral deficiencies, for example, K, Ca, N, Fe, Zn, and Mn, and in some cases even water deficiency (3, 4, 8, 12, 30, 31, 42, 43, 51, 55, 57, 58, 59, 61, 62).

Perhaps the most interesting point in this regard was found in *Vicia faba*, which although inoculated with *Rhizopium radicicola* failed to develop nodules in the absence of boron, and underwent a parasitic attack from its usually contented and well paying symbiotic boarder. This, it is claimed, was due to the host failing to supply the requisite carbohydrate to the symbiont (10, 11).

(c) The vascular defects we have mentioned.

(d) The foliage particularly the older leaves, of boron deficient plants show an excess accumulation of carbohydrates, and lack of protein formation (22, 23, 24, 29, 32, 33, 34, 57, 58). Some evidence indicates that foliage of boron deficient wheat is less resistant to *Puccinia graminis trit* (20) while sucking insects have been found to be more prevalent on boron deficient alfalfa (62).

(e) Storage roots show a decided lack of carbohydrate as the boron nutrition fails, and finally develop regions of dead and dying cells, which give the tissue a water soaked appearance first and eventually dry out, "puck", or become victims to secondary pathogenic attack (6, 7, 12, 15, 16, 17, 21, 22, 27, 28, 29, 30, 36, 44, 46, 47, 52, 55).

This then is a condensed picture of the relation of boron deficiency and external and internal symptoms that may be gathered from the current literature.

## EXPERIMENT

Normal plant material and that showing boron deficiency symptoms was collected from a variety of locations on Long Island and was analyzed for carbohydrate content. Where possible the plants were divided into their various components, leaves, roots, and stems and these parts analyzed quantitatively for reducing sugars, non-reducing sugars and alcohol insoluble polysaccharides.

The material collected in the field consisted of cauliflower in head, turnips, table beets, and mangolds. Boron deficiencies were in all cases determined by symptomology described in the literature upon these crops. Other crops were also found, which might possibly have been suffering from boron deficiency, but as the author was not certain of the symptomology in these cases they were ignored temporarily.

Analysis was effected in the usual method, the exact technique having been previously described (64).

Table I gives the results of this preliminary study. In all cases studied where boron deficiency symptoms occurred, carbohydrates were concentrated in the region of their manufacture, and not translocated to the parts where they are needed. In all cases these plant parts showed a distinct cellular degeneration.

To test this relation further, an experiment was set up in the greenhouse in sand culture, to determine whether a quantitative relationship

TABLE I—SHOWING RELATION BETWEEN CARBOHYDRATE COMPOSITION AND BORON DEFICIENCY IN CERTAIN VEGETABLE CROP PLANTS

Crop	Plant Part	Carbohydrate (Per Cent of Fresh Weight)					
		Hexose		Sucrose		Alcohol Insoluble	
		Normal	Disease	Normal	Disease	Normal	Disease
Turnip . . . . .	Root	4.63	1.55	1.43	0.74	.660	.210
	Foliage	1.16	1.23	0.18	0.33	.085	.203
Cauliflower . . . . .	Foliage	1.50	1.81	0.33	0.43	.010	.109
	Stem	0.90	1.11	1.32	1.46	Nil	Nil
	Curd	1.26	0.54	1.81	1.03	—	—
Beet . . . . .	Root	1.68	1.20	6.63	1.92	—	—
	Foliage	0.38	0.51	Nil	0.28	—	—
Mangold.. . . .	Root	2.40	2.00	2.07	0.83	—	—

existed between the amount of boron fed to the plants and the carbohydrate metabolism.

Turnip was employed as the test plant. All necessary precautions were taken relative to preventing boron contamination of the deficient cultures. With the exception of the differential boron treatments all pots received Shive's solution plus the full quota of minor elements (Br.Cu, Co, Ni, Mn, S, Cr.Hg, Fe, F, I, Zn, Al.). Well fertilized greenhouse compost was employed to grow one series, to serve as a comparison. There were ten replicates in all cases.

The plants were stopped in their growth before the nil boron treatments could die, and fresh weight determinations made on individual plants and plant parts. Composite analytical samples were pickled, and analyzed for carbohydrates. The entire data is given in Table II.

TABLE II—SHOWING EFFECT OF VARIOUS BORON TREATMENTS ON GROWTH AND CARBOHYDRATE COMPOSITION OF TURNIPS

No	Treatment Boron (Ppm.)	Total Weight (Grams)	Weight of Roots (Grams)	Weight of Tops (Grams)	Root/Top Ratio	Carbohydrates Per Cent of Fresh Weights							
						Hexose		Sucrose		Alcohol Insoluble		Appearance	
						Root	Top	Root	Top	Root	Top	Root	Foliage
1	Nil	28.2	15.3	10.8	1.42	.911	1.155	1.356	2.423	.070	.320	Decay	Injured
2	0.05	57.8	37.3	20.5	1.82	1.143	1.179	1.455	2.286	.013	.051	Decay	Injured
3	0.10	209.7	156.4	48.9	3.20	4.128	1.371	5.813	1.792	.234	.023	Some brown Heart	Slight Injury
4	0.50	248.7	193.6	55.1	3.51	5.605	1.203	6.896	1.445	.299	Nil	Very slight Brown Heart	Normal
5	1.00	267.6	217.0	49.8	4.38	3.552	1.672	3.979	2.027	.531	Nil	Normal	Normal
6	10.00	255.8	203.8	52.0	3.92	3.827	1.155	3.842	2.143	.880	.012	Normal	Normal

Difference necessary at 5 per cent  
54.0 22.5 10.3 0.55

From this data it is distinctly evident that where boron was deficient the leaves grew in weight out of proportion to the roots, and were filled with excess carbohydrate in all forms, while the roots showed a marked deficiency in carbohydrates.

Furthermore there appears a direct relation between the amount of boron fed to the plant (up to the therapeutic limit) and the increase in

root size, root top ratio, root carbohydrate and a concomitant decrease in foliage carbohydrate. These changes were directly correlated with vigor and inversely with incidence of brown heart and root decay.

### CONCLUSION

From these results and from the manifold similar findings of the investigations cited previously it appears that at least a tentative hypothesis can be tendered for criticism and further study.

The fact that in boron deficient plants carbohydrates are found to be lacking, in meristem and root, suggests that failure to function is due to lack of adequate energy, supplied normally by respiration of carbohydrates. This particularly applies to roots where plenty of available energy is required to effect absorption of soil minerals against an osmotic and diffusion gradient, in defiance of the Donnan equilibrium.

This slowing up of physiological function is followed, it would seem, by an actual respiration collapse within the cells resulting from a lapse in the carbohydrate supply.

This suggestive hypothesis is now being tested in a variety of ways by the author, and is merely presented here purely for preliminary consideration.

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## A Description of Certain Nutrient Deficiency Symptoms of the Porto Rico Sweetpotato<sup>1</sup>

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THE practicability of conducting experiments to determine the nutrient deficiency symptoms of crop plants is well known. The results greatly assist specialists and growers to recognize disorders in the greenhouse and in the field and to prescribe treatment. Since the sweetpotato is the most important vegetable crop in the south and is grown in a wide variety of soils and climate, the determination of deficiency symptoms of the important nutrients would seem highly desirable.

### MATERIALS AND METHODS

On May 30, 1938, vine cuttings were prepared from plants raised from two individual roots of an individual hill of a Louisiana strain of the Porto Rico sweetpotato and placed in river-bed sand in a greenhouse. On June 15, 24 terminal and 36 basal cuttings were selected from 104 plants and arranged in six comparable lots. In this way each lot comprised four terminal and six basal cuttings.

The plants of each lot were set in 2-gallon, self-draining earthenware jars which contained white river-bed sand. This sand had been previously leached with tap water. Leachings at first were yellowish, probably due to the presence of iron, but they quickly cleared. Coarse glass wool was placed over the drainage outlet to hold the sand in the jars. To promote rapid root growth the plants were allowed to remain in a potting room until June 20. At this time they had the appearance of being firmly established.

The six lots, each of which consisted of 10 plants, were placed on a moderately low platform situated on the east side of a greenhouse. Whenever heavy rains occurred canvas was spread on wires stretched directly above the plants to protect the sand from excessive leaching.

The nutrient solutions used were complete, minus nitrogen, minus phosphorus, minus potassium, minus calcium and minus magnesium. The complete solution consisted of sodium nitrate,  $\text{NaNO}_3$ ; ammonium sulphate,  $(\text{NH}_4)_2\text{SO}_4$ ; potassium dihydrogen phosphate,  $\text{KH}_2\text{PO}_4$ ; magnesium sulphate,  $\text{MgSO}_4$ ; iron tartrate,  $\text{Fe}_2(\text{C}_4\text{H}_4\text{O}_8)_2$ ; manganese sulphate,  $\text{MnSO}_4$ ; and boric acid,  $\text{H}_3\text{BO}_3$ . The ingredients of this solution are not comparable to any commercial fertilizer formula but their effect on plant growth is similar to that of a fairly fertile soil. In the deficiency treatments, sodium was substituted for potassium, calcium and magnesium, and chlorine was substituted for nitrogen and phosphorus. In all treatments the iron, manganese and boron were applied at very dilute concentration.

From June 15 to July 15 all of the plants in all of the lots were given the complete nutrient solution at a rate varying from  $\frac{1}{4}$  to  $\frac{1}{2}$  liter

<sup>1</sup>Technical Contribution No. 61 of the South Carolina Agricultural Experiment Station.

applied thrice weekly. This procedure was followed to allow the plants to develop healthy vines and roots before the deficiency treatments started. The plants grew rapidly and showed no wide differences in growth between the various lots. In general, the plants were normal in every respect and they presented a healthy appearance.

On July 16 the deficiency treatments were started and continued to September 30, when the experiment was terminated. From July 16 to August 15 about 1 liter of solution was applied to each plant three times per week and from August 16 to the end of the experiment from 1 to 2 liters of solution were applied every day.

From the beginning of the experiment and until August 1, the nutrient solutions were adjusted to a pH value from 5.5 to 5.7 and the tap water was adjusted to approximately pH 5.9. At this time, since the leachings were found to be quite acid, the pH of the nutrient solutions was adjusted to a reaction varying from 5.8 to 6.1. The water which had a pH of 6.7 was applied without being acidified.

To measure the response of the plants to the various treatments, the number of branches was counted and the length of the individual stems was measured and recorded at intervals of 2 weeks. Throughout the growing period frequent observations were made on changes in color of the leaves and stems.

## DISCUSSION

*The Complete Nutrient Plants:*—The data on the total length of the vines of the plants which received the various treatments are presented graphically in Fig. 1. These data show that the plants which received the complete nutrient solution grew fairly rapidly throughout the period of the experiment. New stems developed at a fairly constant rate and the length of the vines gradually increased. The mature leaves were moderately large and dark green and the mature stems possessed the characteristic purple pigment of the Porto Rico variety. On September 30, when the experiment was terminated, a few leaves on some of the plants showed mild symptoms of magnesium deficiency.

*The Minus Nitrogen Plants:*—The data show that the plants which received no nitrogen in the nutrient solution made by far the least amount of vine growth. From the time the deficiency treatments started to August 1, the vines developed very slowly and they practically ceased growing by August 15.

Leaf deficiency symptoms first became evident

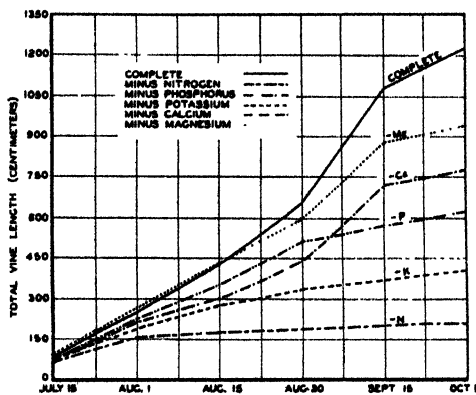


FIG. 1. Effect of treatments on total length of vine.

on July 25, 10 days after the deficiency treatments started. The leaves at the base of the plants became uniformly light green and 4 days later they became yellowish green. At this time the leaves at the tips assumed a light green color. By August 27, 33 days after the deficiency treatments began, the margins of the old leaves became red and the blades turned yellow. About 1 week later, certain areas within these blades assumed a reddish tint. These areas finally turned brown and the leaves abscised. During the last month of the experiment, the first leaf of the growing point was extremely small and dark green. The second and third leaves were slightly larger and yellowish green, the fourth, fifth and sixth leaves had yellow blades with reddish tinted areas and the remainder had developed brown areas or had abscised. Defoliation of the old leaves was quite marked, particularly during the latter part of the experiment. In all cases the petioles of the leaves were shorter than those of the plants which received the complete treatment. The bright yellow and red tinted appearance of the foliage and the scant growth made easily distinguished these plants from those of the other series.

*The Minus Phosphorus Plants:*—The plants which received no phosphorus produced a greater vine growth than those which received no potassium or no nitrogen. During the first 2 weeks after the treatments were started these plants made practically the same amount of growth as those which received the complete nutrient solution. However, growth of the vines gradually declined from August 1 to August 30 and rapidly declined from August 31 to September 30. This decline in growth was due to the development of a small number of new branches, rather than to the development of the individual branches. In fact, the mean length of the vines was slightly greater for the plants which received no phosphorus than for those which received the complete nutrient solution.

Leaf and stem symptoms became evident on August 11, 26 days after the treatments started. At this time the young immature leaves were dark green. About 7 days later the old leaves developed moderately large light yellow areas within the blades. These areas gradually became purple and finally they turned a rich brown. They did not appear in any particular part of the blade. Sometimes they developed in the center; sometimes in the base; sometimes in the margins and sometimes in the tips.

At the close of the experiment, the first leaf at the growing point was small and dark green, the second and third leaves were green, the fourth, fifth and sixth were yellowish green and the remainder developed the characteristic light yellow areas which gradually became purple and finally a rich brown. These areas dropped out of the blades and the leaves abscised. Defoliation was particularly severe during the last 2 weeks of the experiment. The stems which developed after the treatments started were more slender than those which received the complete treatment.

*The Minus Potassium Plants:*—The growth of the plants which received no potassium was moderately rapid from July 15 to August 1 and very slow from August 15 to September 30 (Fig. 1). With the exception of the minus nitrogen plants, these plants made the least

growth. This marked reduction in growth was due primarily to the development of a small number of stems. Evidently a continuous supply of potassium is necessary for the development of new stems.

Leaf symptoms first became evident on August 3, 19 days after the treatments were started. Various areas in the margins of the old leaves became yellowish brown. In 5 or 6 days these areas became brown and the leaf blade became yellow and puckered. On August 11, similar symptoms appeared on the leaves which developed immediately after the treatments were started and, as the experiment continued, they gradually appeared on the leaves to those of the third or fourth nodes from the tips. These dark brown areas at the margins gradually proceeded toward the center of the leaf. This was particularly the case with the old leaves. Defoliation was particularly severe during the last 2 weeks of the experiment. Throughout the experiment the leaves at the tips always remained dark green.

From the time the treatments started and until August 27, the color of the stems did not differ materially from that of plants which received the complete solution. After that time the new stems were more green and slightly more slender than those which received the complete treatment. The scant growth of the vines and the puckered appearance of the leaves easily distinguished these plants from those of the other series.

*The Minus Calcium Plants:*—The data show that the plants which received calcium in the nutrient solution during the first 4 weeks of growth only, made a moderate amount of top growth throughout the period of the experiment. At the end of the experiment, this growth was about 64 per cent of that made by the plants which received the complete solution. Here again this reduction in growth was due primarily to the development of a small number of new shoots. Evidently a continuous supply of calcium as well as nitrogen, phosphorus, potassium and magnesium is necessary for the development of new shoots.

Leaf symptoms first became evident on August 2, 18 days after the deficiency treatments started. Leaves on the new growth became light green. Later, on August 27, certain areas within the margins of four or five leaves at the base of each plant became red. About 7 days later the veins and mesophyll within these areas turned brown. About this time the plants began to develop a small number of thin short laterals which possessed small yellow leaves. These leaves quickly developed brown areas at the margins which gradually proceeded toward the center. The young leaves of the old stems were yellow. Defoliation was not particularly evident on plants of this series. During the period of deficiency treatments the stem color gradually changed from purple to light red.

*The Minus Magnesium Plants:*—The plants which received no magnesium in the nutrient solution grew as rapidly as those which received the complete treatment until about August 15, after which time growth gradually declined (Fig. 1). As in the case of the phosphorus, potassium and calcium deficient plants this decline in growth was due to the development of a comparatively small number of new stems. For all periods the mean branch length was greater and the

mean number of branches was lesser for the magnesium deficient plants than for the plants which received the complete treatment.

Leaf deficiency symptoms appeared relatively early on July 29, 14 days after the treatments started. These symptoms were similar to those of many other herbaceous crops. The intervascular areas changed from dark green to light green and finally to yellow, while the veins remained dark green. This change from green to yellow started at the margins and gradually proceeded toward the center. From September 1 until the end of the experiment the leaves at the fifth, sixth, seventh and eighth nodes showed magnesium deficiency symptoms to a greater extent than those at the other nodes of the plants. Defoliation of these plants was about the same as that of plants which received the complete treatment. The old stems remained normal in color and the new stems were light bluish green.

TABLE I.—WEIGHT OF TOPS AND NUMBER AND MEAN WEIGHT OF ROOTS OF PLANTS OF THE PORTO RICO SWEETPOTATO GROWN IN VARIOUS TREATMENTS (1938)

Top and Root Growth*	Complete	Minus Nitrogen	Minus Phosphorus	Minus Potassium	Minus Magnesium	Minus Calcium
Mean weight tops (grams) . . . . .	1140.3	101.7	402.3	273.2	716.8	964.6
Mean number roots . . . . .	3.8	5.2	3.8	3.2	5.7	3.8
Mean total weight roots (grams) . . . .	350.7	222.1	342.8	95.2	508.1	490.7
Mean weight roots (grams) . . . . .	92.3	42.7	90.2	29.8	89.1	129.1

\*Mean of 10 plants for each treatment.

*Weight of Tops and Weight of Roots:*—The data presented in Table I show the mean weight of tops and the number and mean weight of roots of the plants grown under the various treatments. The deficiency treatments in decreasing order of weight of tops are: minus magnesium which produced 84.6 per cent of those which received the complete treatment, minus calcium which produced 62.9 per cent, minus phosphorus which produced 35.3 per cent, minus potassium which produced 24.0 per cent and minus nitrogen which produced 8.9 per cent. These figures show that a lack of nitrogen, phosphorus or potassium has a much greater influence on the growth of the tops than a lack of magnesium or calcium.

The figures on the mean number and weight of fleshy roots show that the plants which received no calcium in the nutrient solution produced a small number of moderately large roots; those which received no magnesium produced a large number of moderately small roots; those which received no phosphorus or the complete treatment produced a small number of moderately small roots; those which received no nitrogen produced a large number of small roots and those which received no potassium produced a small number of exceedingly small roots. The effect of no potassium in the nutrient solution is particularly striking. It indicates that a continuous supply of potassium is not only necessary for the development of a large number of roots, but also for the development of large sized roots.

Examination of the color of the skin and flesh of the roots of the various lots showed some interesting relationships. Three more or less

distinct groups were evident. The plants which received no nitrogen produced roots which had a dark pink skin and pink flesh; those which received no calcium, or no magnesium, or the complete treatment produced roots which had a light pink skin, and a light pink flesh, and those which received no phosphorus or no potassium produced roots which had a creamy white skin and creamy white flesh. Evidently the proportion of nitrogen to other nutrients and particularly to potassium in the nutrient solution, has an important bearing on the color of the skin and the flesh.

## Boron Deficiency Symptoms in the Genus *Brassica*

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### ABSTRACT

This paper will appear as a Maine Agricultural Experiment Station bulletin.

**S**TUDIES were made in the greenhouse to determine the symptoms of boron deficiency of 11 of the economic plants of the genus *Brassica*. The plants were grown in quartz sand to which the nutrients were added by the continuous flow method. All plants were supplied with boron for a period of 18 days or more. The symptoms of deficiency were found to vary considerably from one kind of plant to another of this genus. The only symptoms common to all kinds of plants were decrease in height of plant, in leaf length, in leaf width and in total weight; and curling and rolling of the leaves. Other symptoms common to a large number of plants were rugosity of the younger leaves and a resemblance of the surface of stems and petioles to cork. Cracking of petioles and chlorosis of leaf blades were symptoms which occurred on a smaller number of plants. The economic part of the plant failed to develop when boron became deficient before that part started to develop. This part of the plant was the one most severely affected regardless of what period of development was characterized by the withholding of boron from the plant.

## Observations on the Effect of Shade on Vegetables<sup>1</sup>

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IN the summer of 1936 a shade house constructed of Sunraytex, a heavy tobacco cloth, was built for the protection of the spinach variety trials from "yellows". In order to determine the relative efficiency of this type of protection, the cloth was placed over only one-half of each row, which was 40 feet in length. Thus, for each of the 24 varieties used, there was 20 feet of row in the open and 20 feet under shade. The soil was uniform, and water was supplied as needed to both plots from an overhead irrigation line.

"Yellows" was not present, but interesting results of another nature were noted. Under shade germination occurred 24 to 48 hours earlier than in the open. The stand was 30 per cent greater, growth was more rapid, leaf area was much greater, plants were darker in color, quality was better in regard to crispness, succulence and flavor, and savoying of savoyed varieties was less under shade conditions than in the open. All varieties showed approximately the same response.

The average weight per plant under the shade was 79.38 grams; in the open, 63.00 grams. This is a mean difference of 16.38 grams, with odds greater than 99:1.

Because of the meager data on environmental conditions in this first experiment, it was repeated in 1938. The set-up was the same as in the previous experiment, but different vegetables were used. No attempt was made to control moisture supply because it was desired to determine the effect of shade on soil moisture. The primary object was to obtain an accurate check on the climatic factors affected by artificial shade, and to observe the response of the vegetables to the changed conditions.

The factors most likely to be influenced by providing a complete cloth enclosure are light intensity, relative humidity, air temperature, soil moisture, and soil temperature. Observations were begun on July 11th, and continued until October 14th. Light intensity at different periods during the day was measured by means of a Weston photometer, Model 622. All readings were taken at plant level. Relative humidity and air temperature were obtained by means of self-recording hygrothermographs. Soil moisture was determined by bringing to constant weight at 60 degrees C samples of soil taken at representative positions, and at 2-inch and 4-inch levels. Soil temperatures were taken at a depth of 3½ inches in the morning, at noon, and in the late afternoon.

Careful observations were made on three kinds and six varieties of vegetables. The vegetables were: radish, Scarlet Globe and Cavalier; lettuce, Grand Rapids, New York 515 and Imperial 44; endive, Green Curled.

<sup>1</sup>Paper No. 187, Department of Vegetable Crops, Cornell University, Ithaca, New York.



## RESULTS AND DISCUSSION

The average air temperature, air humidity, soil temperature and soil moisture for the 14-week period under shade and open conditions, is presented in Table I.

TABLE I—EFFECT OF SHADE ON THE TEMPERATURE AND MOISTURE CONDITIONS OF AIR AND SOIL (JULY 11 TO OCTOBER 14, 1938)

Treatment	Shade	No Shade	Difference	Odds	Significance
Air temperature (degrees F) . . . . .	66.6	65.5	1.1	4:1	Not significant
Relative humidity (per cent) . . . . .	84.1	78.6	5.5	1249:1	Significant
Soil temperature (degrees F) . . . . .	64.7	65.6	0.9	10:1	Not significant
Soil moisture (per cent 2 inch) . . . . .	16.1	12.9	3.2	9999:1	Highly significant
Soil moisture (per cent 4 inch) . . . . .	16.5	14.6	1.9	1999:1	Significant

Purdy (4) reported that in 1933 there was at no time an air temperature difference of more than 2 degrees between shade and open conditions, while Laurie (2) observed that under cloth the temperature was 1 to 3 degrees F higher. Our results agree only in so far as the average difference between shade and no shade is not significant. However, during the hottest and the coolest days differences as great as 7 degrees F have been noted. During very hot weather the air temperature within the shade house was significantly cooler, but it was significantly warmer when outside temperatures were lower. In late September and October, however, there was no pronounced difference between temperatures under shade and outside during the middle of the day. Another important effect of a shade house which does not appear in an analysis of temperature means is the smoothing out of peaks and depressions in the temperature curve. It is possible that in this respect a cloth house would be of value in frost protection and in the maintenance of a more uniform growing temperature.

The work of Garner and Allard (1) indicates no significant difference between soil temperatures under shade and outside at the 3-inch level. Our results are in general agreement. However, although the odds are low they indicate a tendency toward a greater degree of significance than in the case of air temperature. As with air temperature, soil temperatures under cloth were 2 to 7 degrees cooler during very hot weather, and 1 to 3 degrees warmer during cool weather. During the early morning the soil was slightly warmer under shade; from midday until dark it was slightly cooler. As one would expect, soil temperature changes tend to follow air temperature changes but are not as pronounced.

The average relative humidity was significantly higher under shade than outside for the entire season (Table I). These results are in general agreement with both Laurie's (2) and Purdy's (4) observations. With few exceptions the relative humidity was always higher within the house. The greatest differences occurred during the latter part of the day and the early part of the night.

The soil moisture at both the 2- and 4-inch levels was, without exception, higher under shade than outside, the difference being highly significant. The greatest degree of variation occurred at the

2-inch level. Drought conditions existed for a period of 3 weeks during the early part of the growing period. Vegetables under shade grew normally and never exhibited incipient wilting, while outside there were relatively long periods when growth was at a standstill and wilting occurred during the hottest part of the day.

The average light intensity under the shade cloth on a bright day was found to be approximately 53 per cent of that outside. As the intensity outside dropped toward the end of day the difference rapidly decreased. At no time was light a limiting factor, except, possibly on very dull days as suggested by Shantz (6).

In connection with a study of the ecological factors observations on plant growth were made (Table II).

Under shade, with each of the three vegetables studied, germination was stronger, from 24 to 48 hours earlier, and a more uniform stand was obtained. This probably was due to more nearly optimum soil moisture and temperature conditions.

TABLE II—EFFECT OF SHADING ON SOME VEGETABLE PLANTS

Treatment		Radish		Lettuce		Endive
		Scarlet Globe	Cavalier	Grand Rapids	New York 515	Green Curled
Average length of top (Inches) (10 plants)	Shade	8.35	6.53	11.80	8.23	12.3
	No shade	3.25	3.98	6.05	4.90	9.2
	Difference	5.10	2.55	5.75	3.33	3.1
	Odds	1428:1	1666:1	9999:1	9999:1	1666:1
Average green weight of plant (Grams) (10 plants)	Shade	—	—	78.5	84.2	95.3
	No shade	—	—	44.8	35.8	51.0
	Difference	—	—	33.7	48.4	44.3
	Odds	—	—	9999:1	9999:1	4999:1
Average diameter of roots (Inches) (10 roots)	Shade	1.16	1.05	—	—	—
	No shade	.65	.68	—	—	—
	Difference	.51	.37	—	—	—
	Odds	9999:1	1999:1	—	—	—

All of the vegetables developed larger and darker green leaves in the shade than in the open. This is in agreement with much of the earlier work that showed increased leaf area, greater height, and increased concentration of chlorophyll as a result of reduction of light intensity.

In the case of radishes grown under shade tops were longer, roots were larger, crisper, and more uniform both in size and color. Total green and dry weights were greater. Except for the sharp flavor characteristic of radishes grown under high temperatures, those under shade were 100 per cent marketable while those without protection were non-salable. It must be remembered that this crop of radishes was grown during the hottest part of the season; a time when radishes are not normally grown.

Endive also responded favorably to shade. Plants reached marketable maturity much sooner; were larger, greener; had better blanched hearts and were of better flavor than plants grown without protection.

In general, the response of lettuce to shade was similar to that of endive. Considerably larger plants were produced under shade, fol-

lowed by immediate bolting to seed in both Grand Rapids and New York 515. Seeding in Imperial 44 was much less rapid. The plants outside did not form marketable heads but neither did they go to seed until much later, and never to the same extent as under cloth (Table III).

TABLE III—PER CENT OF PLANTS SEEDING UNDER SHADE AND OPEN CONDITIONS

Variety	Days From Planting					
	65		80		100	
	Shade (Per Cent)	No Shade (Per Cent)	Shade (Per Cent)	No Shade (Per Cent)	Shade (Per Cent)	No Shade (Per Cent)
Grand Rapids	100	0	100	0	100	46
New York 515	87	0	99	0	100	92
Imperial 44	0	0	0	0	37	9

Grand Rapids went to seed 100 per cent in 65 days under shade conditions. Outside only 46 per cent had seeded at the end of 100 days. New York 515 did not bolt as completely as Grand Rapids but showed the same trend for early and rapid seeding. Imperial 44, a new variety of the crisp-heading type noted for its resistance to bolting, went to seed very slowly even under shade conditions. However, 37 per cent had seeded under cloth at the end of 100 days, while only 9 per cent had seeded outside.

There may be two possible explanations for this difference in the flowering response of lettuce. First, a lower light intensity prevailing under cloth. Previous work by Garner and Allard (1), and Popp (3) has shown that a very marked reduction in light intensity had no effect on the time of flowering in soybeans. To our knowledge there is no authenticated work reporting a hastening of flowering response due to reduction of light intensity by shading. Schappelle (5) did show, however, that certain short day plants might be induced to flower during a long day if the light intensity was not too great. Second, the extreme check in growth because of lack of water suffered by the plants grown outside may have resulted in retarded seeding. Thompson (7) has shown that a serious check in growth by drying may delay premature seeding in celery. An experiment to test these two hypotheses is now under way.

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## The Effect of Temperature on the Photoperiodic Response of Spinach

By J. E. KNOTT, *Cornell University, Ithaca, N. Y.*

### ABSTRACT

The complete paper will be published as Memoir 218 by the Cornell University Agricultural Experiment Station.

VIRGINIA Savoy and Old Dominion Spinach plants were subjected soon after emergence to temperatures of 40 to 50 degrees, 50 to 60 degrees, 60 to 70 degrees and 70 to 80 degrees F for a 30 day period under the short natural day of winter. When subsequently moved from these temperature ranges and grown at 50 to 60 degrees, 60 to 70 degrees or 70 to 80 degrees F under the gradually lengthening photoperiod, seedstalks appeared first in the plants receiving the 40 to 50 degrees initial temperature treatment, then in plants initially treated at 50 to 60 degrees, 60 to 70 degrees and 70 to 80 degrees F and in that order. The greater the rise in temperature involved in the change, the sooner seedstalks appeared and the shorter the photoperiod necessary for seedstalk initiation.

Plants under a 15-hour day at 40 to 50 degrees F made little growth but when, after a month at 40 to 50 degrees F, they were moved to higher temperatures, the seedstalks appeared in fewer days and the rate of seedstalk elongation was more rapid than in plants which did not receive such low temperature treatment.

Data are given on the effect of temperature and photoperiod on the time to blooming, the rate of seedstalk elongation and the seedstalk height at the time of blooming. Seedstalk development of Old Dominion begun under a 15-hour day could not be arrested by a 7-hour photoperiod at 70 to 80 degrees F. The rapidity of elongation was retarded by moving plants from the 70 to 80 degrees F house to the 60 to 70 degrees F house under a 7-hour day. Elongation was completely arrested at 50 to 60 degrees and 40 to 50 degrees F with a 7-hour day until an increase in light intensity and in amount of sunlight, and a slightly higher temperature caused a resumption of seedstalk growth.

The possible effect of temperature on the production of a flower-promoting hormone is discussed. It is suggested that in field plantings, the temperatures prevailing at different stages of growth exert an important conditioning effect on the rapidity of seedstalk elongation in response of photoperiod.

# The Relation of the Pericarp to Tenderness in Sweet Corn

By D. M. BAILEY, *University of Maine*, and R. M. BAILEY, *Maine Agricultural Experiment Station, Orono, Me.*

**I**N the study of tenderness, open pollinated strains, inbred lines, and hybrids of sweet corn were used which exhibited different indices of tenderness as determined by the pressure test method in 1936. From the varieties tested in 1936, five were chosen for further testing in 1937 and 1938. The varieties used were: Portland Golden Bantam, an open pollinated variety grown extensively in the State of Maine; L-135, a tender inbred Golden Bantam; L-205, a medium tender inbred selected from a cross of Crosby x Golden Bantam; the hybrid of these two inbreds, L-205 x L-135; and Whipcross 6.2, a commercial first generation hybrid.

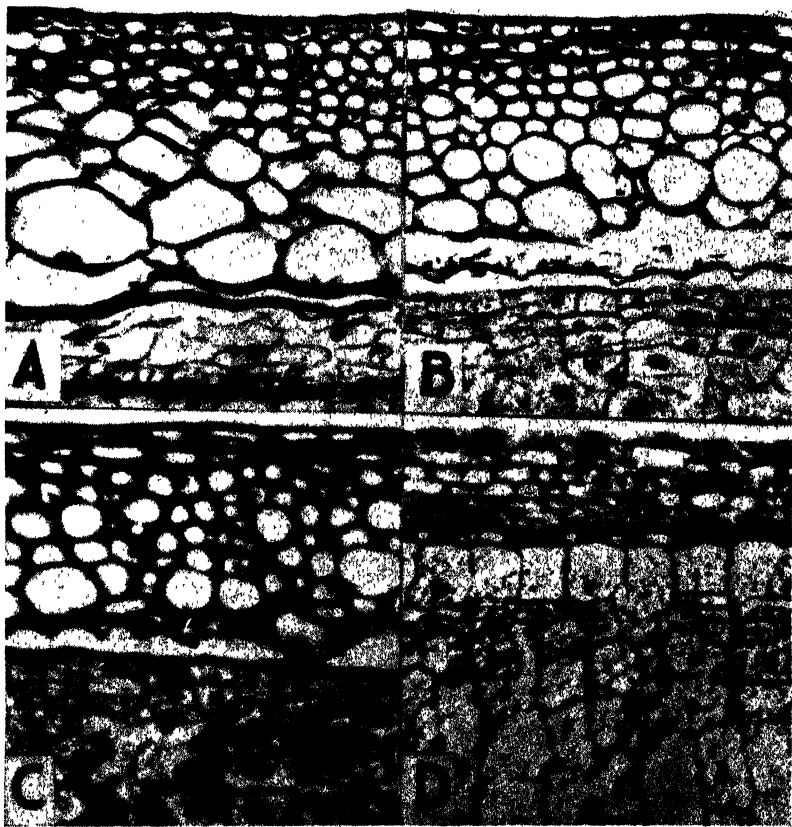


FIG. 1. Pericarp of sweet corn at four dates following pollination. A, 10 days; B, 16 days; C, 19 days; D, 25 days.

Prior to silking the ear shoots were covered with semi-transparent bags and a sizable portion of the silks allowed to emerge from each ear before bulk pollen was collected to sib pollinate each variety. Following pollination the semi-transparent bags were again placed over the ears and allowed to remain until harvest.

Resistance of the pericarp to puncture was determined by the use of a machine similar to the one used and described by Culpepper and Magoon (3). These observations were first made 19 days after pollination and repeated every 3 days until each variety had been tested 31 days after pollination in 1937 and 28 days after pollination in 1938.

In 1937 specimens of the kernels for pericarp study were embedded in paraffin and stained with safranin or Delafield's haematoxylin. In 1938 specimens were killed in considerable quantity, cut free hand, and pericarp measurements made by the use of binoculars magnifying approximately 178 X.

Pericarp measurement and pressure test studies were all confined to the apical center of the kernel.

### RESULTS

Striking similarity in pericarp development of all the varieties under observation was found in a morphological study of the developing pericarp during the pre-canning, canning, and post-canning periods.

The pericarp 10 days (Fig. 1, A) after pollination shows considerable differentiation of the cells in the kernel crown region. The outer pericarp has a predominance of thickened wall, non-nucleate cells, devoid of intercellular spaces. The inner pericarp has already become somewhat resorbed and disintegrated, showing an approaching collapse of this tissue.

During the 16 to 25 days (Fig. 1, B, C, D) after pollination period the inner pericarp, at the kernel crown, becomes a region of crushed,

TABLE I.—MEAN RESISTANCE TO PUNCTURE (IN GRAMS) OF FIVE SWEET CORN VARIETIES ON EACH TEST DATE OF 1937 AND 1938\*

Variety	Days After Pollination				
	19	22	25	28	31
Portland Golden					
Bantam (1937) . . . . .	252.7	259.3	348.7	360.5	377.6
(1938) . . . . .	213.5	249.3	276.0	317.0	—
Whipcross 6.2					
(1937) . . . . .	237.4	289.0	319.5	359.1	354.7
(1938) . . . . .	248.3	271.5	302.2	334.3	—
L—205					
(1937) . . . . .	204.2	232.8	273.4	276.4	290.1
(1938) . . . . .	193.4	209.5	231.8	253.2	—
L—135					
(1937) . . . . .	153.4	173.5	230.2	180.2†	247.4
(1938) . . . . .	232.1	245.8	249.0	251.4	—
L—205 X L—135					
(1937) . . . . .	203.2	256.2	315.0	354.4	346.3
(1938) . . . . .	201.8	223.3	249.8	287.7	—

\*N of each mean 120.

†Usual experimental procedure not followed on this date for this variety. Tests made at night.

partially resorbed and disintegrated cells; it may well be described as a crushed layer in which most of the cells have lost their individuality. The outer pericarp region has become materially thinner. The cell walls have thickened considerably and numerous simple pits in the tangential views are evidenced.

The typical pericarp of the varieties 25 to 31 days (Fig. 1, D) after pollination still shows a decrease in thickness. The shrinkage in pericarp thickness is, however, less outstanding than in the earlier periods. The inner pericarp is crushed and disintegrated with such severity that it is often indistinguishable from the outer pericarp.

### PUNCTURE TEST STUDIES

The mean resistance to puncture of the sweet corn varieties on each date presented in Table I indicates that mean differences occur between varieties and also between maturity dates.

In analysis of the complete data by individual years (Table II, sections A and B) varietal and maturity effects are demonstrated to be highly significant. Varietal and maturity differences are of nearly equal importance where extreme ranges of tenderness are chosen as in this case. Delayed maturity of the inbreds was given careful consideration in the puncture test studies, but histological measurements of the pericarp suggested that this was not the major factor influencing their low resistance to puncture.

TABLE II—ANALYSIS OF VARIANCE OF THE PUNCTURE INDEX OF FIVE SWEET CORN VARIETIES (1937 AND 1938)

Source Variation	Degrees of Freedom	Sum of Squares	Mean Square
<i>Section A (1937)</i>			
Varieties . . . . .	4	6144397.867	1536099.467*
Dates (Maturity) . . . . .	4	5444177.534	1361044.384*
Ears . . . . .	7	117139.127	16734.161
Varieties X dates . . . . .	16	815865.466	50991.591*
Varieties X ears . . . . .	28	254933.373	9104.763
Dates X ears . . . . .	28	212775.039	7599.108
Error (a) between ears . . . . .	112	719397.981	6423.196
Total between ears . . . . .	199	13708686.387	—
Error (b) within ears . . . . .	2800	1326079.980	473.600
Total . . . . .	2999	15034766.367	—
<i>Section B (1938)</i>			
Varieties . . . . .	4	1352740.666	338185.167*
Dates (Maturity) . . . . .	3	1408007.666	469365.889*
Ears . . . . .	7	8111.333	1158.762
Varieties X dates . . . . .	12	288719.000	24059.916*
Varieties X ears . . . . .	28	78355.334	2728.978
Ears X dates . . . . .	21	81396.334	3876.018
Error (a) between ears . . . . .	84	456217.000	5431.154
Total between ears . . . . .	159	3671637.333	—
Error (b) within ears . . . . .	2240	1304780.000	582.491
Total . . . . .	2399	4976417.333	—

\*Exceeds 1 per cent point.

## PERICARP THICKNESS

Pericarp sections of the five varieties were measured for thickness to determine possible varietal differences. A significant varietal difference in pericarp thickness is demonstrated by the data accumulated in 1937 and given in Table III.

TABLE III—ANALYSIS OF VARIANCE OF PERICARP THICKNESS AT THREE DIFFERENT DATES OF MATURITY

Source Variation	Degrees of Freedom	Sum of Squares	Mean Square
Varieties	4	3834.30	958.56*
Dates (Maturity)	2	15288.18	7644.09†
Error (a) between kernels	23	6613.02	287.52
Total between kernels	29	25735.50	
Error (b) within kernels	120	1368.00	11.40
Total	149	27103.50	

\*Exceeds 5 per cent point.

†Exceeds 1 per cent point.

In 1938 larger samples of the same varieties were studied for thickness differences. The summarized data presented in Table IV indicate that important varietal differences occur.

TABLE IV—ANALYSIS OF VARIANCE OF PERICARP THICKNESS IN SWEET CORN HARVESTED AT FOUR DIFFERENT DATES

Source Variation	Degrees of Freedom	Sum of Squares	Mean Square
Dates (Maturity)	3	709.53	236.510*
Varieties	4	1816.92	454.230*
Ears	4	182.02	45.505
Dates X varieties	12	589.38	49.115*
Ears X dates	12	273.32	22.777
Ears X varieties	16	200.56	12.535
Error (a) between ears	48	762.42	15.884
Total between ears	99	4534.15	
Error (b) within ears	400	2858.40	7.146
Total	499	7392.55	

\*Exceeds 1 per cent point.

## SUMMARY

In a study of the relation of the pericarp to tenderness in sweet corn, two hybrids, two inbred lines, and an open pollinated variety were observed for varietal differences in tenderness, pericarp thickness, and pericarp development during pre-canning, canning, and post-canning periods. The pericarp decreases in thickness as the kernel matures. Pericarp resistance to mechanical puncture markedly increases with advancing maturity. Varietal differences in tenderness and pericarp thickness are demonstrated. The varieties with the lowest puncture index at a given stage of maturity were, in general, those with the thinnest pericarp.



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## Temperature and Photoperiod on Seeding and Bulbing in the Onion

By H. C. THOMPSON and ORA SMITH, *Cornell University, Ithaca, N. Y.*

## ABSTRACT

The complete paper has been published as Cornell University Agricultural Experiment Station Bulletin 708.

**R**ESULTS of experiments covering a period of 5 years show that storage temperature has a marked effect on subsequent seedstalk development in the onion, especially when relatively large sets are used. The sets were stored at 30, 32, 40 and 50 degrees F in cold storage and at 50 to 60 degrees and 60 to 70 degrees F in dry storage. The largest percentage of seedstalks was produced by those sets that had been stored over winter at 40 and 50 degrees F. The sets stored at this temperature also produced the lowest yield of marketable bulbs. The best storage temperature of those used were 30 and 32 degrees. The high temperature (60 to 70 degrees) was not satisfactory.

Results of experiments conducted in the greenhouse show the importance of relatively low temperature in seedstalk development. Onion plants grown at 50 to 60 degrees F went to seed under the short days of fall and winter, while at 70 to 80 degrees F seedstalks did not develop either under the short day or under a 15-hour day.

Both relatively high temperature and long photoperiod seem to be essential for bulb formation in Yellow Globe, Red Wethersfield and Ebenezer varieties of onions. Plants grown at 50 to 60 degrees F did not bulb under either a short or a long day. At 60 to 70 degrees and 70 to 80 degrees F bulbing did not take place under the normal day length of winter at Ithaca, New York, but under a 15-hour day bulbing took place at both of these ranges of temperature. Bulbing began at least a month earlier at 70 to 80 degrees than at 60 to 70 degrees F.

## Fertilizer Trials with Asparagus on Peat Sediment Soil

By G. C. HANNA, *University of California, Davis, Calif.*

NUMEROUS attempts to improve yields of asparagus in the Sacramento-San Joaquin Delta area by the application of commercial fertilizers have proved unsuccessful. Annual crops such as onions, celery, and sugar beets have sometimes responded to fertilizers, while potatoes usually respond to applications of phosphate and potash in this area.

In 1930 a fertilizer program, previously described (1) was started to study the effects of different fertilizers with asparagus planted on old asparagus soil immediately after the old crowns were removed. At the same time another series of trials was started on land of the same soil type that had never been planted to asparagus. The trials on replanted soil were replicated three times, each plot consisting of approximately  $\frac{1}{2}$  acre. The plots on virgin asparagus soil were replicated five times; each plot consisted of a row 250 feet in length, with two guard rows between each treatment. The plots were arranged in the same order in all replications, and on the new asparagus soil series no fertilizer trial was more than six rows from the check with which the trial was compared.

The method used in applying the fertilizer was the same in both series. Before planting the crowns the first application was made in the row, after the furrow was opened. The fertilizer was mixed with the first few inches of soil in the bottom of the furrow at least 2 days prior to planting. Subsequent applications were made in four rows, two rows 18 inches on each side of the row of asparagus, and about 18 inches away from the crowns. The fertilizer was applied with a modified potato fertilizer spreader, mounted on an orchard cultivator and was so arranged that the fertilizer could be placed in bands 10 inches below the soil surface in the upper root zone. The winter application was made in February and summer applications were made within a few days after the end of the harvest season. To prevent difference in tillage operations, the fertilizer spreader was used empty on the check plots.

The results of these trials are presented in Table I. Only one trial shows a significant increase in yield, namely, where there was a heavy application of a complete fertilizer applied only before planting, the subsequent annual applications being omitted. This treatment was the only one that did not receive the annual deep tillage operation due the fertilizer applications. Unpublished data at this Station indicate that there is some loss in yield due to deep cultivation. It seems probable that this apparent increase in yield is not a real increase due to the fertilizer used but that there is a decrease on the other plots due to the root pruning by placing the fertilizer 10 inches below the surface.

Table I shows the results of a 4-year crop rotation between removal of the bed and replanting. Plots where alfalfa was used in the rotation show a material increase over alternating with cover crops and barley. Although the increase is significant, the yield is not high enough to be

TABLE I—RESULTS WITH FERTILIZER TRIALS ON ASPARAGUS

Plot	Treatment	Yield Per Acre (Pounds)	Plots Compared	Odds
<i>Comparison of Phosphate Fertilizers on Asparagus (4 Years)</i>				
A	400 Pounds treble super phosphate per acre . . . . .	13,151	A-B = - 353	1:6
B	1000 Pounds super phosphate per acre . . . . .	13,504	A-C = - 206	1:5.4
C	Check . . . . .	13,357	B-C = 147	8.4:1
<i>Comparison of Nitrate Fertilizers on Asparagus (4 Years)</i>				
A	300 Pounds calcium nitrate per acre . . . . .	13,773	A-B = 174	3.7:1
B	300 Pounds sodium nitrate per acre . . . . .	13,599	A-B = 119	2.8:1
C	Check . . . . .	13,654	B-C = - 55	1:1.5
<i>Comparison of Potash Fertilizers on Asparagus (4 Years)</i>				
A	400 pounds muriate of potash per acre . . . . .	13,292	A-B = 5	0
B	400 Pounds sulphate of potash per acre . . . . .	13,287	A-C = - 630	7:1
C	Check . . . . .	12,662	B-C = 625	2.3:1
<i>Comparison of Complete Fertilizers, Summer Versus Winter Application on Asparagus (4 Years)</i>				
A	1000 Pounds super phosphate—Summer application 300 Pounds calcium nitrate 400 Pounds sulphate of potash	12,552	A-B = - 1,818	1:7.2
B	Same as A—Winter application . . . . .	13,734	A-C = - 806	1:10.1
C	Check . . . . .	13,359	B-C = 375	2.4:1
<i>Comparison of Fertilizers, Double Complete Annually Versus Double Complete 1 Year Only on Asparagus (4 Years)</i>				
A	Super phosphate 2,000 pounds per acre . . . . . Calcium nitrate 600 pounds per acre Sulphate of potash 800 pounds per acre	10,149	B-A = 1,279	20:1*
B	Same as A but one year only . . . . .	11,428	B-C = 609	4.5:1
C	Check . . . . .	10,919	C-A = 770	95:1
<i>Comparison of Fertilizers on Asparagus on Replanted Land, Ryer Island (4 Years)</i>				
A	Roots chopped—300 pounds calcium nitrate —400 pounds potassium sulphate —800 pounds treble super-phosphate	5,027	A-B = +185	17.5:1
B	Roots removed—300 pounds sodium nitrate —400 pounds potassium sulphate —800 pounds treble super-phosphate	4,842	A-C = - 12	1:1.2
C	Roots chopped—(Same as B) . . . . .	5,039	B-C = - 197	5.3:1
<i>Comparison of Fertilizers on Asparagus on Replanted Land, Ryer Island (4 Years)</i>				
A	300 Pounds calcium nitrate . . . . .	5,449	A-B = - 193	4.3:1
B	400 Pounds potassium sulphate . . . . .	5,642	A-C = +497	12:1
C	800 Pounds treble super-phosphate . . . . .	4,952	B-C = +690	14.5:1
<i>Comparison of Rotations used Between Removal of old Bed and Replanting Asparagus, Ryer Island (2 Years)</i>				
A	Three years alfalfa . . . . . Fourth year barley	1,907	A-B = 647 pounds in favor of A.	153:1
B	First year and third year leguminous cover crop, second and fourth year barley . . . . .	1,280	— — — — —	— — — — —

\*Considered to be significant although the odds are low. This is due to the spread from year to year when compared in terms of percentage, the yield of the check considered as 100 per cent, the odds are highly significant.

considered a commercial success. Apparently 4 years elapse of time is not sufficient between removal of the old bed and replanting to insure commercial yields under these conditions.

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# Further Studies of Vegetable Plant Growth as Affected by the Position of the Hotbed Heating Cable

By EARL F. BURK<sup>1</sup> and HARRY L. GARVER, *Washington State College, Pullman, Wash.*

**T**HIS paper is a second report of an investigation on the study of plant growth as a result of the position of the heating cable in the hotbed (1). The 1938 tests were run primarily to make further study of the root developments.

## METHODS

Four 6- x 6-foot sections of glass sash covered concrete hotbeds were again used. The heating cables were located in the four beds as follows: bed I, 2 inches above the soil; bed II,  $\frac{1}{2}$  inch below soil surface; bed III, 11 inches below soil surface; and bed IV, 4 inches below soil surface.

The heating cables were arranged so as to be all operated from one thermostat located in bed IV. The thermostat was set at 70 degrees F and the bulb placed 1 inch below the surface of the soil. The ventilation for all beds was approximately the same. The two tests were made from March 5 to April 2 and April 5 to May 5.

## RESULTS

With all beds receiving the same current for heating, there was a difference in air and soil temperatures in the various beds, depending on the location of the cable (Table I).

TABLE I—TEMPERATURES FOR MARCH 15, 1938 (FAHRENHEIT)\*

	Bed I	Bed II	Bed III	Bed IV
Air .....	74	82	60	60
Soil (1 inch below surface) . . .	66	74	66	70

\*This table shows a typical comparison of soil and air temperatures when soil in bed IV was at 70 degrees F without sunlight.

The water requirement for bed II was greatest. For the fourth consecutive test the seeds of the warm season crops, tomatoes, peppers, cucumbers, cantaloupes, and beans, germinated first in bed II. Peppers showed the most pronounced difference in time of germination, requiring 12 days in bed II and 15 days in each of the other beds.

The top growth of the warm season crops after they had come through the soil was most rapid in bed I where the air was the warmest.

There was a considerable difference in the character of the root development of the plants grown in the different beds. This difference was particularly noticeable with the peppers and tomatoes (Fig. 1).

In general, the plants grown in bed I with the cable suspended 2 inches above the soil had comparatively short tap roots and a large number of laterals arising from the first few inches of the tap roots.

<sup>1</sup>On leave of absence 1936-38 from the Oklahoma A. & M. College, Stillwater, Okla.



FIG. 1. Characteristic root growth of peppers and tomato plants 4 weeks after seeding, with the heating cables located in the hot beds as indicated below. The four pairs of both pepper and tomato plants from left to right were grown in beds I, II, III, IV, respectively. The peppers germinated 7 days later than the tomatoes. Roots of tomato plants 10 days prior to those shown above were very similar in type to those of the pepper plants shown above.

Upper left—Cable 2 inches above soil. Upper right—Cable  $\frac{1}{2}$  inch below surface. Lower left—Cable 11 inches below surface. Lower right—Cable 4 inches below surface.

These lateral roots were fairly uniform and of medium length with numerous sublaterals.

The plants in bed II had longer tap roots with laterals less concentrated at the top portion than plants in bed I.

Bed III produced plants having the longest tap and lateral roots. The laterals were long with less sublateral development than in bed II.

The tomato plants in bed IV developed roots with medium long coarse tap and lateral roots, not having many sublaterals, similar to those in bed III but smaller. The roots of the pepper plants more nearly approached those of bed I except that branching was generally lower.

### CONCLUSIONS

The plants grown with the cable closest to the surface again appeared to be the best for transplanting because of their being the earliest and because their type of root system would permit a larger amount of roots retained in digging for transplanting than plants grown in beds III or IV. After the warm season crops were once up, they responded more to a given amount of heat released to warm the air than the same amount released to warm the soil.

Perhaps plants in their development have gone through a natural selection which has brought about an adaptation of the plants to the natural method by which soil acquires its warmth, *vis.* surface heat.

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## Variation in Asparagus in Relation to Size and Shape of Plots

By H. B. CORDNER, *Oklahoma Agricultural and Mechanical College, Stillwater, Okla.*

THE data utilized in the preparation of this paper were secured in 2 years' yield records taken as a preliminary to the establishment of a fertilizer trial with asparagus. The yield data were secured for relatively small plots (14 plants each), after which plots of varying areas and shapes were created by various combinations of these small plots. Variability for the several kinds of plots was determined by the variance method and the results are presented as examples of the variability that might be encountered in asparagus plots of similar size and shape.

### METHODS

A field of sandy loam soil, which appears to be of about average uniformity, was set with 1-year crowns of the variety Mary Washington in the spring of 1935. The plants were set  $2\frac{1}{2}$  feet apart in each of 32 rows with 5 feet between the rows. The field was divided into nine blocks by 2 feet alleyways which crossed the rows at intervals of 35 feet. Leaving the two outside rows as guards, 270 simple plots (5 feet x 35 feet) were provided in a 9 by 30 arrangement.

The field was clean cultivated during the season of 1935 and 1936. The latter season was extremely dry and plant growth was somewhat retarded, and some plants failed entirely. Replanting was practiced by shifting crowns with soil, from an adjacent area planted in 1935.

A harvest season of 63 days in 1937 produced an average yield of 5.8 pounds per plot of 14 plants, with an average spear weight of 0.73 ounces. In 1938, the average weights per plot and per spear were 7.29 pounds and 0.82 ounces respectively. The latter season was more favorable, with a greater abundance of moisture.

The various shapes and areas of plots studied are presented in Table I. The 70 feet plots were formed by combining adjacent 35 feet blocks and by omitting block nine entirely. To secure plots containing either 4, 7 or 8 of the simple 14 plant units, rows 29 and 30 were omitted from the set up. This omission resulted in some increased variability in the 1937 data. The coefficient of variability was used as an expression of the variability of the several kinds of plots.

### RESULTS AND CONCLUSIONS

A rather marked decline in plot variability was noted for the second harvest season. A similar trend was reported by Currence and Richardson (1) whose observations were based on an initial harvest period of 3 years.

Seemingly the plants became more uniformly productive as they became more completely established during this early period. The replanting practiced in 1937 and a favorably moist season in 1938 may have been instrumental in causing the greater uniformity noted for this

TABLE I.—VARIATION IN ASPARAGUS PLOTS OF DIFFERENT SHAPES AND SIZES (VARIANCE EXPRESSED AS PER CENT OF PLOT MEANS, BASED ON WEIGHTS OF HARVESTED ASPARAGUS SPEARS)

Kind of Plot		1937				1938			
Number Rows*	Number 14-Plant Units	Total	Block	Row	Remainder	Total	Block	Row	Remainder
<i>Rows 35 Feet Long (14 Plants)</i>									
1	1	71.1	59.5	33.1	20.3	49.5	36.0	28.6	18.6
2	2	52.6	42.1	27.8	15.0	38.0	25.4	25.2	12.7
3	3	43.2	34.4	23.2	11.9	31.4	20.8	21.2	11.2
4	4	38.4	30.4	19.8	12.7	24.5	16.2	15.5	10.0
5	5	31.4	26.6	12.7	10.8	23.3	16.6	14.2	9.0
6	6	28.6	24.3	11.7	9.5	18.6	14.7	8.9	7.2
7	7	25.5	23.0	6.2	9.3	20.4	12.3	14.7	7.0
<i>Rows 70 Feet Long (28 Plants)</i>									
1	2	47.5	34.7	23.5	10.4	45.9	37.6	22.4	14.1
2	4	34.2	24.8	20.0	12.7	32.9	26.6	19.4	10.1
3	6	28.3	20.1	17.2	9.9	29.3	21.8	17.7	8.7
4	8	26.3	18.7	14.5	11.3	22.8	16.7	13.1	8.3

\*Rows 5 feet apart.

latter season. However, a relatively low correlation ( $-.280 \pm .006$ ) was found between the number of missing hills and the yield per plot for the 1938 season.

As is to be expected, the decrease in variability became proportionately less as the plot size was increased by the successive addition of the 14 plant units. For most purposes, it does not appear to be practical to use plots larger than the equivalent of four to five of these units. As indicated, the residual errors for plots of this size were from 9 to 10 per cent of the means.

Referring to the fertilizer study that is being organized, it is believed that plots consisting of four 35 feet rows would be most practical. This would permit a 6 by 9 arrangement of plots, with suitable guard and buffer rows. These plots would have an area of approximately 1/60-acre and differences of about 8 to 10 per cent of the means of "treatments" would be significant.

There appears to be no special advantage in the use of plots 70 feet long as compared to 35 feet plots of equal areas. Assuming that the 1938 data are more indicative of the actual variability of the field, and it is believed that this is true, plots of 35 feet length are more desirable.

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## Root Growth and Distribution of the Perfection Pimento (*Capsicum Frutescens* var. *Grossum*)

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### ABSTRACT

This paper will be published in full in the *Journal of Agricultural Research*.

AS soon as the pimiento seed germinates in the hot bed, which usually takes about 10 days, the young primary root typically grows directly downward. After 2 months' time in the hot bed, and with relatively good care the plants are well hardened and ready to be transplanted to the field. At this stage the primary root extends down to about the 10- to 12-inch level and is well supplied with laterals measuring from 4 to 10 inches in length and about 0.6 millimeters in diameter.

The primary or tap root is usually more or less damaged in the process of transplanting. It appears that the now remaining short portion of the tap root does not make up a very important part of the root system as such, but from this and the base of the stem arise many laterals that continue to develop and eventually constitute a very efficient absorbing system. These roots grow horizontally outward to vertically downward and by the time they have been in the field 60 days they completely occupy the first foot of soil on all sides of the plant to a depth of 14 inches. By August the larger and more deeply penetrating roots extend outward 40 inches from the base of the plant and downward as deep as 26 inches. Mature or 8 months old plants have a root spread of 48 to 52 inches with many of the once horizontal laterals being found in the second foot of soil. Very few roots penetrate the stiff clay subsoil any deeper than 24 inches.

# The Effect of Various Seedling Treatments on Growth and Yield of Early Grano Onions

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## ABSTRACT

This paper will be published in full in *Scientific Agriculture*.

SIX seed and seedling treatments were studied. Observations on the effect of each treatment were made during the growing season, and yield data secured when the onions were mature. Average size of bulbs harvested corresponded very closely with the vigor and development of plants observed and recorded during the growing season; that is, the stronger the vigor the larger the bulbs.

With one exception average weight of tops and roots corresponded with average weight of bulbs. Transplanting in itself did not bring about increased size or yield of bulbs, but transplanting and top-dressing with commercial fertilizer gave increased returns.

Seedlings that were checked in growth by being subjected to low temperatures and by having top growth clipped off at intervals gave a yield of about 50 per cent that of seedlings sown later, grown under favorable conditions for growth, and forced by the application of commercial fertilizer.

Results indicated that high yields of Early Grano onions may be secured if seed is sown indoors comparatively late (early in April), and the seedlings forced by applications of commercial fertilizer. By this method the cost of handling and producing the crop may be greatly reduced.

## Curing Temperature in Relation to Storage Quality of Three Varieties of Sweet Potatoes

By H. B. CORDNER, *Oklahoma Agricultural and Mechanical College,  
Stillwater, Okla.*

THE desirability of curing roots of sweet potatoes in preparation for storage is generally recognized. Wound healing appears to be the principal reason for this treatment and Artschwager and Starrett (1) have shown that temperatures of 84 to 90 degrees F, in conjunction with relative humidities of 70 per cent or higher, are desirable for effecting rapid healing of wounds on sweet potato roots. Ordinarily, artificial heat would be required at harvest time to secure an effective curing temperature, although Kimbrough (2) has shown that roots of the Porto Rico variety may be cured and stored successfully without the use of artificial heat in southern Louisiana.

In the present study of curing, the temperature was investigated with special reference to three varieties, namely, Nancy Hall, Porto Rico, and Maryland Golden. The latter was included as a member of the Jersey group and is generally found to be more difficult to keep in storage than the other two varieties.

### MATERIALS AND METHODS

Roots of the three varieties were harvested November 11 and Grade I and "strings" were packed into  $\frac{1}{2}$ -bushel baskets with lids. The roots remained in these baskets throughout the storage period. A total of 21 baskets each of the varieties Nancy Hall and Maryland Golden were packed. Due to lack of material only nine baskets of Porto Rico roots were prepared. The net and gross weights of each package were determined.

The baskets were divided into three equal lots, each lot being placed to cure at one of three different temperatures in special chambers. These chambers (3 feet x 3 feet x 7 feet) are equipped with four shelves, an electric fan and an electric heater with thermostat control. Vents at top and bottom provide for the renewal of air. Temperature and humidity were recorded by means of a hygrothermograph which was shifted from chamber to chamber during the curing period at about 8 hour intervals. The temperature record indicated a maximum deviation of about 2 degrees F with means of 92, 80, and 70 degrees F, respectively, for the three chambers.

The relative humidity in all chambers was at about 70 per cent during the early curing period and declined to about 36 per cent at the end of the period. It is possible that the actual moisture content of the atmosphere within the closed baskets was somewhat higher than this.

The baskets of potatoes were weighed at 2- to 3-day intervals during the 15-day curing period, rotating the baskets from shelf to shelf at each weighing. After curing, the roots were transferred to the main storage room which was heated with a gas stove with a manual control. An effort was made to maintain a temperature of 50 to 60

degrees F, although some deviation from this range occurred, especially during the latter part of the storage season. Weight losses during storage were determined by weighing the baskets at about weekly intervals. After a storage period of 120 days, on March 26 the roots were removed from storage and carefully examined as to quality.

### DISCUSSION AND CONCLUSIONS

The weight losses as given in Table I were estimated as per cent of the original weights of the roots. In most cases the shrinkage during the 15-day curing period exceeded the loss of weight during 120 days in storage. The loss during the curing period was usually greatest at 92 degrees F, but such differences were largely compensated for during the storage interval, making the final loss approximately equal for all lots of roots of the same variety. String roots of the varieties Porto Rico and Maryland Golden cured at 70 degrees F were exceptional in that the total loss greatly exceeded that for roots cured at the higher temperatures. Rather marked varietal responses were noted as regards the loss of weight in curing and in storage. As an average, Grade I roots of Nancy Hall lost but 18 per cent as compared to the total losses of 23 and 31 per cent respectively for Porto Rico and Maryland Golden.

TABLE I—WEIGHT LOSSES OF SWEET POTATO ROOTS IN RELATION TO CURING TEMPERATURE\* (LOSS EXPRESSED AS PER CENT OF ORIGINAL WEIGHT)

Variety	Curing Temperature (Degrees F)	Grade 1 Roots				String Roots			
		End of Curing	Mid-Storage	End of Storage	During Storage	End of Curing	Mid-Storage	End of Storage	During Storage
Nancy Hall	92	9.1	14.5	18.8	9.7	12.3	18.6	23.1	10.8
	80	10.5	15.0	18.9	8.4	12.1	17.5	22.7	10.6
	70	8.7	13.5	17.4	8.7	12.1	18.13	23.3	11.2
Average		9.4	14.3	18.4	8.9	12.2	18.2	23.0	10.9
Porto Rico	92	12.1	17.7	22.9	10.8	16.5	25.6	34.1	17.6
	80	11.8	17.5	22.7	10.9	17.7	26.6	34.3	16.6
	70	10.7	17.2	22.4	11.7	17.2	28.8	38.2	21.0
Average		11.5	17.5	22.7	11.1	17.1	27.0	35.5	18.4
Maryland Golden	92	16.7	24.3	31.4	14.7	18.0	26.2	33.7	15.7
	80	14.2	22.8	30.4	16.2	16.5	25.6	33.8	17.3
	70	12.6	22.0	30.3	17.7	17.0	30.6	42.2	25.2
Average		14.5	23.0	30.7	16.2	17.2	27.5	36.6	19.4

\*Roots cured 15 days followed by storage at about 50 to 60 degrees F for 120 days.

The actual quality of the roots at the end of the storage period indicated rather striking differences in relation to varieties and curing temperatures as shown in Table II. The superior keeping quality of the roots of the Nancy Hall variety is clearly indicated. In most instances best quality resulted when the roots were cured at 92 degrees F. This is especially true of the varieties Porto Rico and Maryland Golden, where greater shriveling and decay of roots resulted in storage following curing at the lower temperatures.

TABLE II—FINAL QUALITY OF THE SWEET POTATO ROOTS AFTER STORAGE FOR 120 DAYS (EXPRESSED AS PER CENT OF FINAL WEIGHT, MARCH 26, 1938)

Variety	Curing Temperature (Degrees F)	Grade 1 Roots				String Roots			
		Roots Sound	Roots Shriveled		Storage Rots	Roots Sound	Roots Shriveled		Storage Rots
			Mod-erately	Se-verely			Mod-erately	Se-verely	
Nancy Hall	92	99.0	0.7	0.3	—	100.	—	—	—
	80	99.1	0.9	—	—	93.9	1.0	5.1	—
	70	98.1	0.8	1.1	—	95.1	2.1	2.8	—
Porto Rico	92	100.	—	—	—	78.5	6.9	14.6	—
	80	94.9	2.3	2.8	—	76.0	6.6	17.4	—
	70	86.	4.5	9.0	0.5	68.8	6.1	23.8	1.3
Maryland Golden	92	83.5	7.9	7.2	1.5	55.3	27.0	11.8	5.8
	80	78.1	11.6	8.7	1.6	32.1	35.4	22.3	10.2
	70	75.5	12.8	8.3	3.4	34.6	23.6	16.0	25.5

Some sprouting took place in the roots during curing and the sprouts developed slowly during storage. Sprouting was encouraged by high temperatures during curing and was most evident in the case of the roots of Nancy Hall. Under the circumstances, it was concluded that sprout development did not appreciably affect the trends for shriveling and weight losses.

The results of this study indicate that roots of the variety Nancy Hall shrink least in storage and keep satisfactorily following curing at temperatures as low as 70 degrees F. Porto Rico roots kept best in storage following curing at 92 degrees F with slightly greater storage losses following curing at 80 degrees F. The greatest storage losses were found in the case of roots of the Maryland Golden, where it appears to be imperative that a high curing temperature (about 90 degrees F) be used. It appears to be desirable to give some attention, in the future, to relative humidity in the storage environment in order to avoid the shriveling of roots of this latter variety.

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## Elimination of Apical Dominance in the Potato Tuber

By NORWOOD C. THORNTON, *Boyce Thompson Institute,  
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### ABSTRACT

The complete paper will appear in the *Contributions from Boyce Thompson Institute*.

**D**ORMANCY exists in freshly-harvested potatoes because the bud tissue is exposed to too much oxygen and the dormancy continues until the periderm or "skin" of the tuber thickens to such an extent that it retards the penetration of oxygen. Storage of freshly-harvested potatoes in an atmosphere containing only 2 to 10 per cent of oxygen (carbon dioxide being removed) will result in sprouting of the tubers within 7 to 9 days whereas the same tubers stored in 20 per cent (normal content of the atmosphere) or higher percentages of oxygen will not sprout until 6 or more weeks later.

Dormant potatoes, germinating rapidly in reduced percentages of oxygen (2 to 10 per cent), produce many sprouts per eye in all eyes of the tuber, thus apical dominance of the seed end over the stem end, as well as apical dominance of the top bud over the lateral buds of each eye is broken. This is contrary to the normal production of sprouts by the potato where apical dominance is in force and only one sprout is produced in the topmost eye of the seed end of the tuber. Three or four sprouts, usually four, can be obtained from each eye of the whole tuber or from one-eye pieces of the tuber if held in reduced percentages of oxygen as compared with one sprout on the one-eye pieces held in a normal percentage of oxygen. When sprouted pieces of potato from reduced oxygen treatments are planted in soil more than one plant is produced from each piece which is not in accordance with the usual result where only one plant is produced by a one-eye piece of tuber that has been exposed to the normal amount of oxygen present in the atmosphere.

# Foliar Diagnosis: Nutritional Differences Affecting the Yields of Potatoes from Similarly Treated Plots<sup>1</sup>

By WALTER THOMAS and WARREN B. MACK, *Pennsylvania State College, State College, Pa.*

## INTRODUCTION

IT has been shown (1, 3, 4) that the method of foliar diagnosis faithfully reflects the differences in nutrition with respect to nitrogen, phosphoric acid, and potash resulting from different fertilizer treatments—differences in nutrition which are associated or correlated with yields.

When the soil, therefore, is relatively homogeneous the foliar diagnosis of similarly treated plots are similar, within a sufficient approximation for field experiments. When, however, the soil of couplets similarly fertilized is distinctly heterogeneous in character, as for example, when the soil of one of the couplets has been eroded, with consequent changes in its chemical and physical character, the composition of homologous leaves of similarly treated couplets may differ considerably, particularly with respect to potash, invariably resulting in a higher potash content of the leaf of plants growing on the eroded plots (5).

These results led to an investigation to determine the relationship to that of potash of the two other dominant bases, *viz.*, lime and magnesia. The findings, reported elsewhere (6, 8), indicated that *under optimum conditions* a linear relationship exists between the three bases: CaO, MgO, and K<sub>2</sub>O and also between any two of these variables, throughout the growth cycle; and that, furthermore, departure with respect to form and position from this optimum equilibrium is an indication of lack of physiological balance with respect to lime, magnesia, and potash reflected in reduced growth.

The object of the present investigation is to examine the relationships of all five dominant "entities", nitrogen, phosphoric acid, potash, lime, and magnesia, to the development and yields of potatoes growing on duplicate plots treated similarly, but in which the soil of certain pairs is known to be markedly heterogeneous.

## MATERIALS AND METHODS

The potato plants (var. Rural Russet) were grown in 1937 on tiers 1, 2, 4, and 5 of section D of the vegetable fertility plots. Planting was carried out on May 19 and 20; the fertilizers were broadcast by hand and were harrowed into the upper 3 inches of soil before planting was begun.

The plants developed normally up to the first week in August, when the foliage began to present an abnormal appearance owing to injury from the leaf hopper (*Empoasca mali*) which could not be successfully

<sup>1</sup>Authorized for publication on December 9, 1938, as Paper No. 880 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

controlled by the sprays used (cuprous oxide, Lethane 440, and Lethane spreader) to avoid contamination of the leaves with calcium. At the last sampling date, August 25, the lower leaves (the first six in most plants) were either dead or badly injured, and on the manure plots (No. 1-15 and No. 4-3) the eleventh leaf was the oldest available for sampling on this date.

### PRESENTATION OF RESULTS

The absolute and relative yields from the different treatments are shown in Table I.

TABLE I—PLOT TREATMENTS WITH YIELDS OF TUBERS

Tier	Plot	Fertilizer Applied (Pounds)	Symbol	Yields (Pounds)	Relative Yields $\frac{A-B}{A} \times 100$
1	2	3.75 Nitrate of soda	N	36 (A)	-40.5
4	16			50.6 (B)	
1	3	6.25 Superphosphate	P	43.6 (A)	-38.5
4	15			60.4 (B)	
1	4	1.60 Muriate of potash	K	49.7 (A)	-44.8
4	14			72.0 (B)	
1	6	3.75 Nitrate of soda	NP	50.3 (A)	-45.3
4	12	6.25 Superphosphate		73.1 (B)	
1	7	3.75 Nitrate of soda	NK	48.1 (A)	-39.7
4	11	1.60 Muriate of potash		67.2 (B)	
1	8	6.25 Superphosphate	PK	76.6 (A)	-25.3
4	10	1.60 Muriate of potash		96.3 (B)	
1	10	3.75 Nitrate of soda		105.0 (A)	
4	8	6.25 Superphosphate	NPK	106.0 (B)	- 0.9
		1.60 Muriate of potash			
2	4	5.625 Nitrate of soda		67.0 (A)	
5	14	6.25 Superphosphate	(1.5N)PK	82.1 (B)	-22.5
		1.60 Muriate of potash			
2	8	3.75 Nitrate of soda		84.5 (A)	
5	10	9.375 Superphosphate	N(1.5P)K	110.1 (B)	-30.2
		1.60 Muriate of potash			
2	12	3.75 Nitrate of soda		90.1 (A)	
5	6	6.25 Superphosphate	NP(1.5K)	97.9 (B)	- 8.6
		2.40 Muriate of potash			
2	15	5.625 Nitrate of soda		79.8 (A)	
5	3	9.375 Superphosphate	1.5(NPK)	74.5 (B)	+ 6.6
		2.40 Muriate of potash			
1	15	600 Manure	Manure	124 (A)	+21.8
4	3			97 (B)	

The analytical results showing the percentage values for N,  $P_2O_5$ ,  $K_2O$ ,  $CaO$ , and  $MgO$  in the chosen leaf at the dates of sampling indicated are given in columns 4, 5, 6, 8, and 9 of Table II.

The values shown on July 2, July 16, and August 5 are for the fourth leaf, and for the sixth or seventh leaf on August 20, except in manure (No. 1-15 and No. 4-3), in which, as already mentioned, the oldest leaves available were the eleventh. This shift in sampling will not greatly affect the results from plants growing on plots receiving mineral fertilizers, but in the manure samples of August 20, the values for N and  $P_2O_5$  will be higher and the values for  $K_2O$ ,  $CaO$ , and  $MgO$  lower than would have been obtained if the fourth leaf had been available.

From base to tip in the potato plant, the percentages of nitrogen and phosphoric acid of the leaf progressively increase and those for  $K_2O$ ,  $CaO$ , and  $MgO$  progressively decrease. In other words the younger



the leaf the higher the percentages of N and  $P_2O_5$  and the lower the percentages of  $K_2O$ ,  $CaO$ , and  $MgO$ .

## DISCUSSION AND INTERPRETATION OF RESULTS

### I. DEFINITION OF TERMS

In a discussion of the physiological ontogeny of an organ like the leaf, it is necessary to define terms and units. Consequently, to avoid ambiguity essential definitions are repeated here:

1. The composition is based on the dry matter of the leaf without taking into consideration the weight of the dry material at each sampling or of the number of leaves sampled.

2. The quantitative index expressing the effects of any one fertilizer element at the moment of sampling the leaves from any one plot is the ratio of the amount of that element contained in the leaves of the plant growing on the plot considered, to the amount of that element in the morphologically homologous leaves of a plant growing on a plot receiving no fertilizer, sampled at the same time (1, 2).

3. The *quantity* or intensity of nutrition of the selected leaves consists of the sum ( $N + P_2O_5 + K_2O$ ) of each element at the moment of sampling expressed as a percentage of the dried material (1, 2).

4. The *quality* of nutrition is the ratio of these entities to each other also at the moment of sampling and is conveniently expressed as a composite *NPK-unit* in trilinear co-ordinates (1, 2).

5. No physiological significance can be attributed to the foliar diagnosis of any one fertilizer treatment considered alone. Foliar diagnosis considered independently of all other field data and of other foliar diagnosis has no physiological significance. In other words, the method is comparative, just as is the method of analysis of the entire plant.

6. An interpretation of fertilizer action by the method of foliar diagnosis requires a departure from the traditional way, by which the yield from a given plot is related to the fertilizer applied. The relation between the development and yield of a plant and its nutrition as reflected in the composition of its leaves is more direct than that between the development and yield and the fertilizer applied. Differences in yield of similarly treated plots, attributed in the traditional method to chance variations of soil and other unknown sources of error, in the method of foliar diagnosis are related to experimentally determined facts of nutrition.

### II. TYPICAL RESPONSE TO FERTILIZERS ON HAGERSTOWN SOILS

The yields given in Table I are typical of fertilizer response on Hagerstown soils. These soils respond to the application of each one of the "entities", nitrogen, phosphoric acid, and potash, and the yield is greater, in general, when all three elements are applied. Growth and development on this soil type consequently are limited in general by the deficiency of all three of these nutritive elements.

TABLE II—PERCENTAGES OF N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, AND MgO IN THE DRIED FOLIAGE, TOGETHER WITH THE MILLIGRAM EQUIVALENTS OF N, P<sub>2</sub>O<sub>5</sub>, AND K<sub>2</sub>O AND THE COMPOSITION OF THE NPK-UNITS FOR THE DIFFERENT TREATMENTS, AT FOUR SAMPLING PERIODS

Date of Sampling	Treatment	Tier and Plot	Dried Foliage					Milligram Equivalents					Composition of <i>NPK-Ustil</i>		
			N (M <sub>2</sub> ) (Per Cent)	P <sub>2</sub> O <sub>5</sub> (M <sub>2</sub> ) (Per Cent)	K <sub>2</sub> O (M <sub>2</sub> ) (Per Cent)	N + P <sub>2</sub> O <sub>5</sub> + K <sub>2</sub> O (s)	CaO	MgO	N (B <sub>x</sub> )	P <sub>2</sub> O <sub>5</sub> (B <sub>y</sub> )	K <sub>2</sub> O (B <sub>z</sub> )	E <sub>x</sub> + E <sub>y</sub> + E <sub>z</sub> (S)	X (100 $\frac{E_x}{S}$ ) (N)	Y (100 $\frac{E_y}{S}$ ) (P <sub>2</sub> O <sub>5</sub> )	Z (100 $\frac{E_z}{S}$ ) (K <sub>2</sub> O)
July 2..... July 16..... August 5..... August 20.....	Manure	1-15	4.870	0.704	6.317	11.891	3.360	1.133	347.718	26.779	134.552	512.049	67.90	5.82	26.27
			3.560	0.526	5.620	9.706	4.396	1.303	254.184	22.249	119.706	396.139	64.17	5.61	30.21
			3.160	0.464	5.368	8.982	3.948	1.072	224.910	19.637	114.338	356.875	62.67	5.46	31.86
			3.080	0.436	5.194	8.710	3.976	1.104	219.912	18.442	110.732	349.086	62.99	5.28	31.72
July 2..... July 16..... August 5..... August 20.....	Manure	4-3	4.410	0.640	6.066	11.116	3.274	1.339	314.874	27.072	129.206	471.152	66.83	5.74	27.42
			3.520	0.526	5.839	9.885	4.322	1.636	251.328	22.249	124.370	397.947	63.16	5.59	31.25
			3.050	0.414	4.593	8.057	4.078	1.412	217.770	17.512	97.830	333.112	65.37	5.25	29.37
			3.190	0.400	5.000	8.590	3.503	1.376	227.766	17.968	106.500	352.234	64.66	5.10	30.23
July 2..... July 16..... August 5..... August 20.....	1.5 (NPK)	2-15	4.820	0.652	6.872	12.344	3.556	0.641	344.148	27.579	146.373	518.100	66.42	5.32	28.25
			4.000	0.526	6.589	11.115	4.396	0.709	285.600	22.249	140.345	448.194	63.72	4.96	31.31
			3.300	0.430	5.542	9.272	4.718	0.832	235.620	18.189	118.044	371.853	63.39	4.89	31.71
			3.100	0.386	4.844	8.330	4.900	0.807	221.340	16.328	103.177	340.845	64.94	4.79	30.26
July 2..... July 16..... August 5..... August 20.....	1.5 (NPK)	5-3	4.620	0.694	6.201	11.515	3.164	0.917	329.868	29.356	132.081	491.305	67.14	5.97	26.88
			3.900	0.610	5.930	10.440	4.356	1.520	278.846	25.803	126.309	430.958	64.70	5.98	29.31
			3.160	0.366	6.290	8.836	4.942	1.719	225.624	16.427	112.677	354.728	63.60	4.63	31.76
			3.150	0.358	4.225	7.733	4.602	1.774	224.910	15.143	89.992	330.045	68.14	4.58	27.27
July 2..... July 16..... August 5..... August 20.....	NP (1.5K)	2-12	4.720	0.592	6.822	12.134	3.360	0.554	337.008	25.042	145.308	507.358	66.42	4.93	28.64
			3.960	0.468	6.860	11.308	4.354	0.851	282.744	19.796	146.544	449.084	62.96	4.40	32.63
			3.190	0.360	6.008	9.557	5.152	0.851	227.760	15.228	127.949	370.937	61.40	4.10	34.49
			3.200	0.370	4.980	8.550	4.620	0.869	228.480	15.651	106.074	350.206	65.24	4.46	30.29
July 2..... July 16..... August 5..... August 20.....	NP (1.5K)	5-6	4.760	0.638	7.085	12.493	3.461	0.615	339.864	26.987	150.910	517.761	65.64	5.21	29.14
			3.980	0.516	6.725	11.221	4.566	0.814	284.172	21.829	143.242	449.243	63.25	4.85	31.89
			3.020	0.396	4.418	7.834	6.060	0.905	215.628	16.751	94.103	326.452	66.04	5.13	28.82
			3.040	0.344	5.019	8.403	5.456	0.869	217.056	14.551	106.904	338.511	64.12	4.29	31.56
July 2..... July 16..... August 5..... August 20.....	N (1.5P) K	2-8	4.860	0.758	6.450	12.068	3.724	0.753	347.004	22.003	137.385	516.452	67.19	6.21	28.59
			3.950	0.556	6.027	10.513	4.966	0.916	282.030	22.673	128.375	453.078	65.12	5.23	29.64
			3.260	0.414	5.315	8.189	5.330	1.066	232.764	17.612	96.169	346.445	67.18	5.05	27.76
			3.010	0.364	3.449	6.843	5.642	1.122	214.914	16.243	73.463	304.620	70.55	6.33	24.11

July 2	N (1.5P) K	5-10	4.730	0.670	5.457	10.957	3.819	0.561	337.722	28.341	116.234	482.297	70.02	5.89	24.10
July 16			3.700	0.514	4.767	8.987	3.669	0.831	231.160	15.481	101.537	387.459	68.18	5.61	26.20
August 5			3.240	0.366	5.271	8.877	4.882	0.977	202.776	15.566	86.566	369.089	64.42	4.31	31.26
August 20			2.840	0.368	4.205	7.413	3.959	1.068				307.908	65.85	5.05	29.09
July 2	(1.5N) PK	2-4	5.020	0.504	5.824	11.448	3.320	0.641	358.428	25.126	124.264	507.818	70.58	4.94	24.47
July 16			4.260	0.570	5.434	11.204	4.380	0.778	304.164	21.573	137.044	462.781	65.72	4.66	29.61
August 5			3.520	0.372	5.387	8.279	4.858	0.807	231.328	15.331	114.743	381.806	65.82	4.12	30.05
August 20			3.380	0.362	4.845	8.587	4.760	0.887	241.332	15.312	103.198	359.842	67.06	4.25	28.68
July 2	(1.5N) PK	5-14	4.580	0.558	6.527	11.645	3.231	0.615	325.584	23.603	139.025	488.212	66.68	4.83	28.48
July 16			4.010	0.486	6.128	10.620	4.222	0.814	286.314	20.557	130.441	437.312	65.47	4.70	29.82
August 5			3.140	0.364	5.620	9.364	4.925	0.814	239.904	16.243	119.706	375.853	63.83	4.32	31.94
August 20			3.210	0.354	4.573	8.137	4.997	0.809	229.194	14.974	97.404	341.572	67.10	4.38	28.51
July 2	NPK	1-10	4.630	0.588	5.969	11.197	4.032	0.677	330.582	25.295	127.139	483.016	68.43	5.23	26.33
July 16			3.530	0.482	5.794	9.806	5.586	0.869	252.042	20.388	123.412	395.842	63.67	5.15	31.17
August 5			3.140	0.362	4.632	8.160	5.922	1.028	224.196	16.835	98.661	339.692	65.99	4.96	29.04
August 20			2.950	0.376	3.895	7.221	5.530	1.129	210.630	15.904	82.963	309.497	68.05	5.13	26.81
July 2	NPK	4-8	4.860	0.608	6.589	12.057	3.360	0.615	347.004	25.718	140.345	513.067	67.63	5.01	27.35
July 16			3.810	0.398	5.794	10.002	4.537	0.814	272.034	16.835	123.412	412.281	65.98	4.08	29.93
August 5			3.240	0.398	4.360	7.998	5.216	0.923	231.336	16.835	92.868	341.039	67.83	4.93	27.23
August 20			3.060	0.352	3.876	7.288	4.607	1.104	218.480	14.889	82.558	315.927	69.15	4.71	26.13
July 2	PK	1-8	4.480	0.602	5.698	10.760	3.400	0.579	318.494	25.494	121.367	465.275	68.44	5.47	26.08
July 16			3.470	0.468	5.504	9.442	4.210	0.669	247.758	19.796	117.235	384.789	64.38	5.14	30.47
August 5			2.760	0.442	5.039	8.241	5.016	0.687	197.064	18.696	107.330	323.090	60.99	5.78	33.22
August 20			2.640	0.400	3.313	6.353	4.860	0.669	188.496	16.920	70.566	275.982	68.30	6.13	25.56
July 2	PK	4-10	4.300	0.622	5.213	10.135	3.704	0.579	307.020	26.310	111.037	444.367	69.09	5.92	24.98
July 16			3.400	0.492	5.058	8.950	4.595	0.822	242.276	17.850	107.735	370.991	65.30	5.65	29.04
August 5			3.010	0.422	4.584	7.986	4.882	0.798	214.910	17.850	97.000	329.760	65.17	5.41	29.41
August 20			2.300	0.392	4.263	6.955	5.385	0.778	164.220	16.581	90.801	271.602	60.46	6.10	33.43
July 2	NK	1-7	4.710	0.428	5.581	10.719	2.632	0.980	336.294	18.104	118.875	473.273	71.05	3.82	25.12
July 16			4.110	0.334	5.872	10.616	2.940	1.086	314.874	14.128	125.073	454.075	69.34	3.11	27.55
August 5			3.580	0.374	5.039	9.273	3.696	1.303	275.604	15.820	107.330	398.754	69.14	3.97	26.88
August 20			3.260	0.318	4.496	8.074	3.892	1.285	232.764	13.451	95.764	341.979	68.06	3.93	28.00
July 2	NK	4-11	4.480	0.430	6.345	11.255	2.642	0.579	319.872	18.189	135.148	473.209	67.60	3.84	28.55
July 16			4.100	0.386	5.891	10.677	2.986	0.597	314.416	16.328	125.478	456.222	69.28	3.53	27.18
August 5			3.710	0.420	5.348	9.478	4.221	0.796	264.894	17.766	111.762	394.442	67.15	4.50	28.34
August 20			3.480	0.380	4.922	8.782	4.279	0.771	248.472	16.074	104.838	369.384	67.26	4.35	28.38
July 2	NP	1-6	4.950	0.616	2.848	8.414	4.494	1.187	353.430	26.568	60.662	440.660	90.20	6.03	13.76
July 16			4.180	0.438	1.918	6.516	5.796	1.593	297.024	18.527	40.853	356.404	83.23	5.19	11.47
August 5			3.460	0.436	1.508	5.404	5.726	1.738	247.044	18.443	32.120	297.607	83.01	6.19	10.79
August 20			3.240	0.400	1.124	4.764	4.676	1.919	231.336	16.920	23.941	272.197	84.98	6.21	8.80

TABLE II—Continued

Date of Sampling	Treatment	Tier and Plot	Dried Foliage					Milligram Equivalents				Composition of NPK-Uvit			
			N (Mx) (Per Cent)	P <sub>2</sub> O <sub>5</sub> (My) (Per Cent)	K <sub>2</sub> O (Mz) (Per Cent)	N + P <sub>2</sub> O <sub>5</sub> + K <sub>2</sub> O (s)	CaO	MgO	N (Ex)	P <sub>2</sub> O <sub>5</sub> (Ey)	K <sub>2</sub> O (Ez)	E <sub>x</sub> + E <sub>y</sub> + E <sub>z</sub> (S)	X (100 S) (N)	Y (100 S) (P <sub>2</sub> O <sub>5</sub> )	Z (100 S) (K <sub>2</sub> O)
July 2 .....	NP	4-12	4.830	0.554	4.283	9.967	4.049	0.778	344.862	23.434	91.228	459.524	75.05	5.09	19.85
July 16 .....			4.000	0.444	2.945	7.389	6.002	1.158	285.900	18.781	62.728	367.109	77.79	5.11	17.10
August 5 .....			3.510	0.404	1.891	5.805	6.289	1.448	250.614	17.089	40.278	307.981	81.37	5.54	13.08
August 20 .....	K	1-4	3.010	0.374	1.337	4.721	5.744	1.484	214.914	15.820	28.478	259.212	82.91	6.10	10.98
July 2 .....			4.240	0.506	5.562	10.308	2.362	0.652	302.736	15.404	118.470	442.610	88.39	4.83	26.77
July 16 .....			3.760	0.370	5.833	9.993	2.772	0.669	268.464	15.651	124.244	408.359	85.74	3.83	30.42
August 5 .....	K	4-14	3.080	0.436	5.232	8.748	3.572	0.742	219.912	18.428	109.311	347.651	63.25	5.30	31.44
August 20 .....			3.050	0.392	4.624	8.066	3.710	0.706	217.770	16.581	98.491	332.842	65.42	4.98	29.59
July 2 .....	P	1-3	4.180	0.422	6.202	10.804	2.896	0.517	298.452	17.851	132.102	448.405	66.55	3.98	29.46
July 16 .....			4.050	0.386	6.066	10.502	3.259	0.561	288.170	16.328	129.205	434.703	66.52	3.75	29.92
August 5 .....			3.210	0.366	4.612	8.198	4.408	0.706	229.194	15.482	98.235	342.911	66.84	4.51	28.64
August 20 .....	P	4-15	2.580	0.378	3.953	6.911	4.374	0.669	184.212	15.989	84.199	284.400	64.77	5.62	29.60
July 2 .....			4.660	0.640	3.023	8.323	4.250	1.014	332.724	27.072	64.390	424.186	78.43	6.38	15.18
July 16 .....			3.680	0.464	2.240	6.384	5.320	1.112	262.752	19.627	47.712	330.081	79.59	5.94	14.46
August 5 .....	P	4-15	2.560	0.464	1.628	4.652	7.000	1.940	182.784	19.637	34.676	237.087	77.09	8.27	14.63
August 20 .....			2.500	0.438	1.465	4.403	5.570	1.860	178.500	18.527	31.204	228.231	78.21	8.12	13.66
July 2 .....	N	1-2	4.130	0.562	4.430	9.122	3.594	0.561	294.882	23.772	94.869	413.013	71.39	5.75	22.84
July 16 .....			3.540	0.472	3.314	7.736	5.474	0.843	252.756	19.965	70.588	343.509	73.62	5.81	20.56
August 5 .....			3.040	0.466	2.395	5.761	5.885	0.894	207.600	18.965	51.013	278.038	74.47	7.16	18.34
August 20 .....	N	4-16	2.340	0.472	1.589	4.401	5.831	1.115	167.076	19.965	33.845	230.866	75.63	9.04	15.32
July 2 .....			4.720	0.400	3.353	8.473	2.906	1.249	337.008	16.920	71.410	435.347	70.23	3.97	16.79
July 16 .....			4.320	0.324	3.507	7.168	3.626	1.521	308.448	14.758	71.832	395.229	78.24	3.57	18.18
August 5 .....	N	4-16	3.810	0.404	3.357	7.567	4.536	1.830	272.034	17.089	71.410	380.542	73.44	4.16	19.80
August 20 .....			3.430	0.374	2.209	6.013	4.032	1.810	244.902	15.820	47.082	307.774	79.57	5.74	15.28
July 2 .....	N	4-16	4.370	0.376	3.818	8.564	3.951	0.922	312.018	15.904	81.233	409.245	76.24	2.98	19.87
July 16 .....			4.430	0.404	3.469	8.303	4.212	1.278	316.302	17.089	73.889	407.280	77.66	2.98	18.44
August 5 .....			3.900	0.514	2.259	6.673	5.145	1.647	278.480	21.742	48.116	348.318	70.93	6.24	15.81
August 20 .....			3.230	0.382	2.131	5.743	4.609	1.629	230.082	16.158	45.390	291.610	78.89	5.55	15.36

### III. INDICATIONS GIVEN BY THE GRAPHS SHOWING THE PERCENTAGES OF N, $P_2O_5$ , $K_2O$ , $CaO$ , AND $MgO$ IN THE SELECTED LEAF AS ORDINATES AND DATES OF SAMPLING AS ABSCISSAE

(a) *Method of Interpretation*.—This graphic method of presentation is shown in Fig. 1 and has the advantage that the course of nutrition of all five "entities" can be shown simultaneously. The slope of a graph indicates the resultant of import into and of export from the leaf of an element or "entity". Thus a steep downward gradient of an element which normally is present in progressively diminishing amounts as the leaf ages, namely, N,  $P_2O_5$ , and  $K_2O$ , indicates large demand relative to supply of that element. Similarly a steep upward gradient of the graphs of these elements is indicative of relatively small demand to that of supply, or a "bottling up" of that element in the leaf, showing lack of utilization.

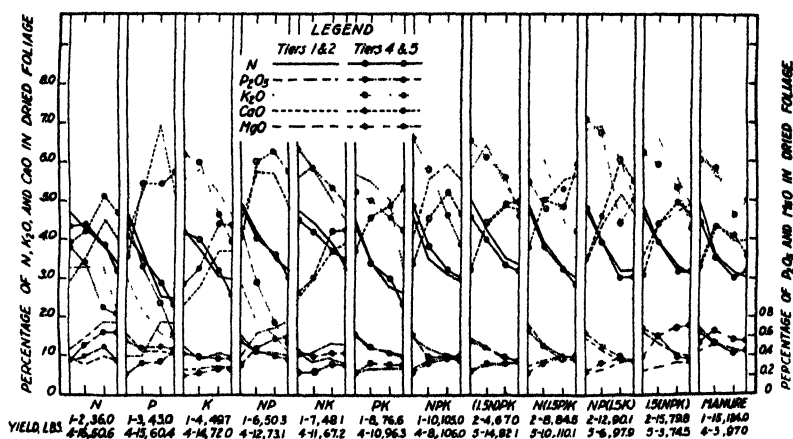


FIG. 1. Graphs showing the percentages of N,  $P_2O_5$ ,  $K_2O$ ,  $CaO$ , and  $MgO$  in the selected leaf as ordinates and periods of sampling as abscissae.

The graphs for these elements of which the quantities normally increase as the leaf ages, namely  $CaO$  and  $MgO$  must be appropriately interpreted. In Fig. 1 it will be noticed that after the third sampling date (August 5) the graphs for  $CaO$  turn downwards in many cases. The significance of this apparently abnormal course is not as yet revealed.

(b) *The Nitrogen Graphs*.—In Fig. 1 the nitrogen content of the leaf of plants which received nitrogen fertilizer is higher at the first sampling date than that of those which received none, with one exception, P(No. 1-3). On July 2, P(No. 1-3) has a nitrogen content greater by 0.03 per cent and on July 16 by 0.15 per cent than that of NPK (No. 1-10). But the superiority of the nitrogen content of this plot receiving phosphorus only does not continue, for by August 5 the nitrogen content of P(No. 1-3) sinks to the lowest level resulting from any of the treatments. The fact that the rate of supply is inade-

quate in the plots without nitrogen is indicated by the steep gradient of the N graphs of [P], [K] and [PK] and by their low levels in both tiers 1 and 4.

With the exceptions listed below, the positions and forms of the nitrogen graphs of similarly treated couplets do not differ greatly when due consideration is given to the fact that the experiments are conducted under field conditions and with a plant as capricious as the potato. In most couplets the difference is less than 5 per cent, except in [P] on July 2, [K] on August 20, [NK] on July 2 and August 5, [PK] on August 20, and [(1.5N)PK] on July 2 when the difference exceeds 10 per cent.

At first blush this fact would suggest that the large differences in the yields of couplets are not the result of differences in nitrogen nutrition (absorption and utilization). This suggestion finds confirmation in the fact that although a relationship exists between the content of nitrogen in the leaf and the presence of nitrogen in the fertilizer, there is no apparent relationship between the content of nitrogen in the leaf and the yield, nor between nitrogen in the fertilizer and the yield.

(c) *The Phosphoric Acid Graphs*:—In Fig. 1 the  $P_2O_5$  content of the leaves of plants growing on plots that received phosphate application is higher during the first period than that of those which received none. But this superiority of the content of  $P_2O_5$  does not always continue, for because of accumulation (non-utilization) of  $P_2O_5$  later in the growth cycle in the leaves of plants that did not receive phosphate additions ([N], [K], [NK]), the  $P_2O_5$  content of the leaves from plants on these plots is frequently greater than that of plants receiving phosphate additions, viz., [(1.5N)PK], [N(1.5P)K], [NP(1.5K)] and [1.5(NPK)]. This accumulation of  $P_2O_5$  in the leaves of potato plants from plots which did not receive any phosphate has always been observed in our potato experiments. In some years accumulation takes place during the first period. The phenomenon is attributed to a rise in temperature which has facilitated absorption but not utilization of phosphoric acid, because of a lack of equilibrium (1).

The positions and forms of the  $P_2O_5$  graphs of similarly treated couplets in general do not differ greatly. But the relative differences are greater than in the case of nitrogen. During most of the cycle in most treatments the differences are less than 10 per cent; exceptions are [N] on July 16 and August 5, [K] on August 5, [NK] on July 16 and August 5, and [NPK] on July 16.

A phosphoric acid content of the leaf declining from 0.64 to 0.40 per cent during the growth cycle is sufficient for optimum growth of the potato in this year, as indicated by the graph of the manure plot (No. 1-15). The  $P_2O_5$  graphs of [N], [P] (tier 4), [K], [NP], [NK], [PK], [NPK], [(1.5N)PK], and [NP(1.5K)] are below those of the optimum (No. 1-15) during the whole cycle, as are also [N(1.5P)K] and [1.5(NPK)] during the second and third periods.

There is consequently a relationship between phosphoric acid in the leaf and its presence in the fertilizer, between  $P_2O_5$  in the leaf and the

yield, but none between the presence of  $P_2O_5$  in the fertilizer and the yield unless potassium also is present.

(d) *The Potash Graphs*:—The  $K_2O$  content of the leaves of plants growing on plots which received potash is much greater than that of those which received none throughout the whole period, and, furthermore, the content of the leaves from those plots which received greater amounts of potash than the standard fertilizer, *viz.*, [NP(1.5K)] and [1.5(NPK)], is higher at the first date of sampling than is that of the others.

The positions and very steep gradients of the  $K_2O$  graphs of [P] and [NP] compared with that of [N] are noteworthy. Phosphorus either with or without nitrogen additions therefore has caused a greater utilization of potash than has the application of nitrogen alone.

The differences in the positions and forms of the graphs of similarly treated couplets are much greater than in the case of either the nitrogen or the phosphoric acid graphs. The least divergence in the yields of couplets is in [NPK] where the graphs for  $K_2O$  coincide after the middle of the first period. It is significant, too, that in most cases the higher yielding member of a couplet has a higher content of  $K_2O$  in the leaf on the first sampling date, July 6. The exceptions are [N(1.5P)K] and [PK] in which the  $K_2O$  content of the higher yielding couplet does not exceed that of its duplicate until after the middle of the second period and the last period. In most treatments the  $K_2O$  graph of the higher yielding duplicate is above that of its couplet during the whole cycle. A content of  $K_2O$  in the leaf varying from 6.32 to 5.20 per cent during the cycle was adequate for optimum growth of the potato during this year. These limits were never reached at any time during the growth cycle in the lowest yielding plots [N], [P], [K], and [NP]. Moreover, the graphs of all the mineral fertilizer treatments fall below that of the optimum during the latter period of the growth cycle.

There is, therefore, a correlation between the content of  $K_2O$  in the leaf and its presence in the fertilizer, between  $K_2O$  in the leaf and the yield, but none between  $K_2O$  in the fertilizer and the yield except when phosphorus also is supplied.

These N,  $P_2O_5$ , and  $K_2O$  graphs then faithfully reflect the variations in the nutrition among differently fertilized plots, which are not always indicated by the appearance of the vegetation.

(e) *The Calcium Graphs*:—On May 11, 1937, finely ground non-magnesium limestone was applied to each of the plots. The amount added to each plot was such as was estimated to bring the plots to approximately the same hydrogen-ion concentration.

Because experimental plots may have the same pH values it does not necessarily follow that the calcium nutrition will be identical in the plants growing thereon. The relationship among the bases must be considered (6). If one base, say potash, is deficient, the plant will absorb larger quantities of another base (lime or magnesia) in attempts to maintain the optimum hydrogen-ion concentration of its tissues.

Furthermore, although calcium present in superphosphate is not an effective neutralizer of soil acids, calcium in this form is easily absorbed

by plants and contributes to differential nutrition, with respect to this element. This is indicated by a comparison of the foliar diagnosis of plots with and without superphosphate. This fact has been established experimentally by the method of foliar diagnosis for maize (7) and is again in full evidence in the present experiment as shown by the calcium graphs of plots receiving superphosphate without potash, *viz.*, in [P] and in [NP] — the Ca graphs of which are higher than those of the other treatments.

Except in the manure plots and also in the (1.5N)PK plots, the graphs for calcium of similarly treated couplets are widely separated throughout the whole cycle in [N], [K], [PK], and [NPK] and during a portion of the cycle in [P], [NP], [NK], [N(1.5P)K], [NP(1.5K)], and [1.5(NPK)].

(f) *The Magnesia Graphs*:—The MgO graphs of duplicate couplets vary widely in [P], [NP], [NK], and [1.5(NPK)]. The relationship to yields is complex, and can be accurately indicated only by the method described in an earlier paper (8) that is, by examining the physiological balance between  $K_2O$ , MgO, and CaO.

#### IV. INDICATIONS GIVEN BY THE GRAPHS SHOWING THE INTENSITIES OF NUTRITION AND THE COMPOSITION OF THE NPK-UNITS

##### (a) *The Intensities of Nutrition*

Of the commercial fertilizer treatments [P], [NP], [N], and [PK] have resulted in the lowest *intensities of nutrition* as determined by the mean of the values for each treatment throughout the cycle. Potash is the dominant factor leading to increased *intensity of nutrition*. A very low *intensity of nutrition* is always associated with low yields; and a good equilibrium with respect to NPK cannot compensate for this condition. A high *intensity of nutrition*, however, may compensate in part for a poor equilibrium.

##### (b) *The Trilinear Co-ordinate Graphs*

1. *Graphs of the N Treatments, N(No. 1-2, No. 4-16) Fig. 2*:—At the first sampling the nitrogen and potash in the *NPK-unit* of the lower yielding duplicate No. 1-2 are displaced further from those of the optimum *NPK-unit* (manure No. 1-15) than are those of No. 4-16. From then until the third sampling the drift of the  $N-P_2O_5-K_2O$  equilibrium is in opposite directions; the proportions of nitrogen and potash in No. 4-16 recede further from the optimum, and that of phosphoric acid approaches the optimum.

2. *Graphs of the P Treatments, P(No. 1-3, No. 4-15) Fig. 2*:—The graphs of these couplets are widely separated in position and differ also greatly in form. Although the  $N-P_2O_5-K_2O$  equilibrium is nearer the optimum throughout the cycle in No. 4-15 the drift is away from the optimum with respect to all three entities as the leaf ages. But the addition of phosphate alone is an unfavorable factor in both couplets, as is shown by the fact that the relative proportions of phosphoric acid recede farther from the optimum with increasing age of the leaf.



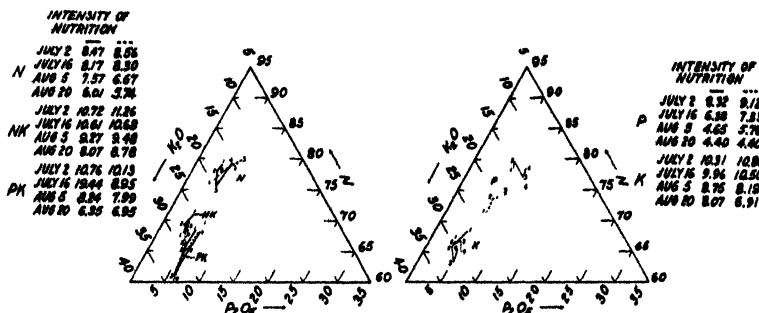


FIG. 2. Graphs showing the *NPK-units* in trilinear co-ordinates for N, P, K, NK, and PK, together with the intensity of nutrition at each of the four sampling periods. Solid lines are for plots in tiers 1 and 2 and dotted lines are for their respective duplicates, tiers 4 and 5.

3. *Graphs of the K Treatments, K (No. 1-4, No. 4-14) Fig. 2:*—The graph of No. 4-14 is characterized by a relatively small displacement of the  $N-P_2O_5-K_2O$  equilibrium during the cycle compared with that of No. 1-4, resulting in widely separated co-ordinates in the first and third samplings. Resistance during the first two periods to the natural declining tendency with respect to nitrogen of the medium (soil and meteorological factors) is evident in No. 4-14.

4. *Graphs of the NK Treatments, NK (No. 1-7, No. 4-11) Fig. 2:*—The proportion of phosphoric acid in the *NPK-unit* in both couplets is far below the optimum, but is higher in No. 4-11, the higher yielding member of the couplet throughout the cycle. The proportion of N in the *NPK-unit* in No. 1-7 is relatively much too high at all samplings and that of  $K_2O$  is too low.

5. *Graphs of the PK Treatments, PK (No. 1-8, No. 4-10) Fig. 2:*—The proportion of nitrogen and of phosphoric acid in the *NPK-unit* of both plots decreases during the first period. N continues to decrease relatively in both during the second period with phosphoric acid increasing in No. 1-8 and decreasing in No. 4-10. During the last period the drift of nitrogen is in opposite directions, increasing in No. 1-8 and decreasing in No. 4-10.

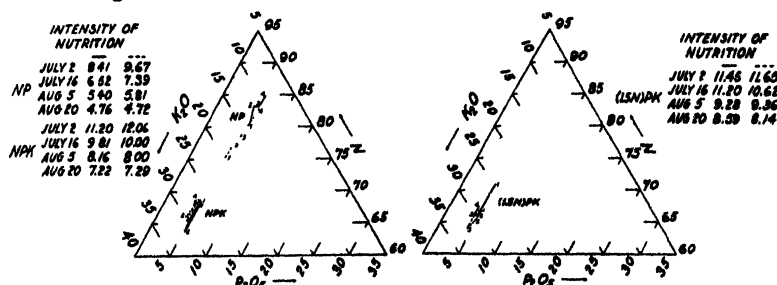


FIG. 3. Graphs showing the *NPK-units* in trilinear co-ordinates for NP, NPK, and (1.5N)PK, together with the intensity of nutrition at each of the four sampling periods. Solid lines are for plots in tiers 1 and 2 and dotted lines are for their respective duplicates, tiers 4 and 5.

6. *Graphs of the NP Treatments, NP (No. 1-6, No. 4-12) Fig. 3:*—The graphs of both No. 1-6 and No. 4-12 show a considerable displacement of the  $N-P_2O_5-K_2O$  equilibrium in the direction of greater N and somewhat greater  $P_2O_5$ , throughout the cycle; the displacement of the latter is greater than that of the former, although the former is further out of balance with respect to N.

7. *Graphs of the NPK Treatments, NPK (No. 1-10, No. 4-8) Fig. 3:*—The difference between the yields of these couplets is relatively small, but the foliar diagnosis shows what neither the appearance of the plants nor the yields have indicated, the existence of differences in the course of nutrition with respect to N-P-K, and that with respect to the optimum  $N-P_2O_5-K_2O$  equilibrium these differences are in favor of the lower yielding plot. These results suggest that foliar diagnoses may be a better indicator of nutritional differences than are the yields.

8. *Graphs of the (1.5N)PK Treatments, (1.5N)PK (No. 2-4, No. 5-14) Fig. 3:*—The co-ordinates of the lower yielding couplet (No. 2-4) are displaced higher and further from the optimum throughout the cycle. The characteristic of the graph of this plot No. 2-4 is the abnormally low proportion of  $K_2O$  in the *NPK-unit* at the first sampling. In both couplets the proportion of  $P_2O_5$  in the *NPK-unit* is too low relative to the optimum.

9. *Graphs of the N(1.5P)K Treatments, N(1.5P)K (No. 2-8, No. 5-10) Fig. 4:*—The displacements of the graphs are very unlike. Starting from an abnormally low proportion of  $K_2O$  there is a marked increase, with advancing age of the leaf, in the proportion of  $K_2O$  in the *NPK-unit* of the higher yielding duplicate No. 5-10, made at the expense of the nitrogen which continually decreases during the cycle. In No. 2-8, on the other hand, nitrogen increases after the second sampling on July 16, and  $K_2O$  continually decreases to a very low level, well below the optimum.

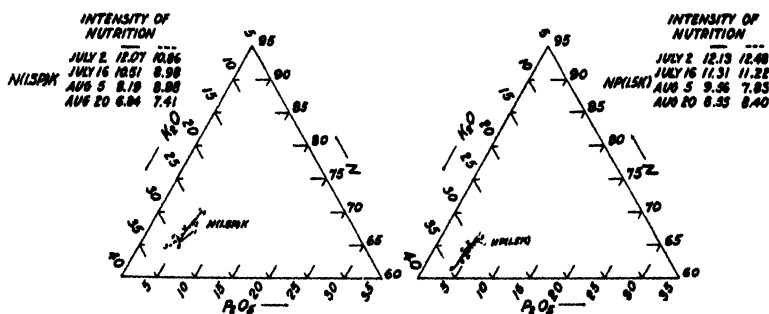


FIG. 4. Graphs showing the *NPK-units* in trilinear co-ordinates for N(1.5P)K and NP(1.5K) together with the intensity of nutrition at each of the four sampling periods. Solid lines are for plots in tiers 1 and 2 and dotted lines for their respective duplicates, tiers 4 and 5.

10. *Graphs of the NP(1.5K) Treatments, NP(1.5K) (No. 2-12, No. 5-6) Fig. 4:*—The proportion of  $K_2O$  in the *NPK-unit* of No.

2-12 rises rapidly during the first two periods; the increases are made at the expense of the nitrogen and phosphoric acid. In No. 5-6, the higher yielding duplicate on the other hand, the proportion of  $K_2O$  in the *NPK-unit* is higher at the beginning, and after increasing during the first period declines during the second, and ends at about the same proportion as that reached during the second sampling. The characteristic of the graph of the lower yielding duplicate is the declining proportion of  $P_2O_5$  in the *NPK-unit* to very low levels for a plot treated with phosphate applications.

11. *Graphs of the 1.5(NPK) Treatments, 1.5(NPK) (No. 2-4, No. 5-10)* Fig. 5:—Nitrogen in both couplets continually declines during the first two periods. During most of the cycle  $K_2O$  in the higher yielding duplicate is higher than in that of the lower yielding plot. The characteristic differences in the graphs are the marked displacements of the  $P_2O_5$ . During the first period,  $P_2O_5$  in the *NPK-unit* of No. 5-10 is much greater than in that of No. 2-4, after which the situation is reversed.

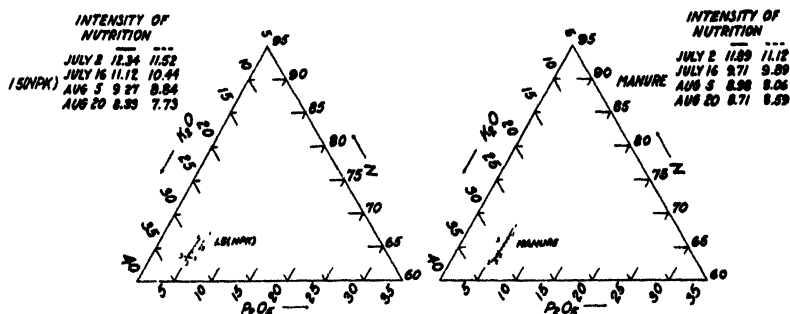


FIG. 5. Graphs showing the *NPK-units* in trilinear co-ordinates for 1.5(NPK) and manure together with the intensity of nutrition at each of the four sampling periods. Solid lines are for plots in tiers 1 and 2 and dotted lines are for their respective duplicates, tiers 4 and 5.

12. *Graphs of the Manure Treatments, Manure (No. 1-15, No. 4-3)* Fig. 5:—The proportion of  $K_2O$  in the unit of the higher yielding duplicate (No. 1-15) increases during the first two periods, after which there is little change. The characteristic of the graph of the higher yielding duplicate is the higher proportion of  $P_2O_5$  in the *NPK-unit* throughout the whole period.

(c) *Simplification of the Interpretation of the Differences in the  $N-P_2O_5-K_2O$  Equilibrium Resulting from the Different Treatments by a Consideration of the Mean Values of the *NPK-units* and of the Intensities During the Cycle*

Table III and Fig. 6 show the positions of the mean value of the *NPK-units* during the cycle. These means represent for each treatment the center of gravity of the detailed diagrams in Figs. 2 to 5.

The position of the mean *NPK-unit* of the duplicate plot in tiers 4 and 5, respectively, is shown by means of a cross (x). The solid straight lines join the position of the mean *NPK-units* of each couplet,

TABLE III—THE MEAN VALUES DURING THE CYCLE OF THE INTENSITIES, THE NPK-UNITS AND THE CA, MG, K-UNIT

Fertilizer	Tier	Plot	Mean Intensity	Mean NPK-Unit			Mean Ca Mg K-Unit			Yields
N	1	2	7.56	78.12	4.26	17.51	47.95	28.41	23.62	36.5
	4	16	7.31	78.18	4.96	16.84	54.96	23.31	21.71	50.6
P	1	3	5.94	78.33	7.18	14.48	62.22	22.86	14.90	43.6
	4	15	6.66	73.78	6.90	19.22	62.97	14.66	22.36	60.4
K	1	4	9.27	65.70	4.73	29.55	41.99	13.54	44.45	49.7
	4	14	9.10	66.18	4.42	29.31	48.30	11.09	40.60	72.0
NP	1	6	6.27	82.88	5.90	11.20	60.41	26.48	13.09	50.5
	4	12	6.89	79.28	5.46	15.25	62.50	19.19	18.29	73.1
NK	1	7	9.67	69.39	3.70	26.89	40.82	19.84	39.32	48.1
	4	11	10.05	67.82	4.01	28.13	44.59	12.13	43.27	67.2
PK	1	8	8.70	65.53	5.63	28.84	53.26	11.10	35.63	76.6
	4	10	8.50	65.04	5.73	29.23	54.21	12.13	33.66	96.3
NPK	1	10	9.10	66.53	5.12	28.34	54.71	13.45	31.83	105.0
	4	8	9.33	67.60	4.64	27.62	50.70	13.82	35.49	106.0
(1.5N)PK	2	4	10.12	67.25	4.45	28.24	49.14	12.36	38.49	67.0
	5	14	9.94	65.73	4.51	29.62	49.18	12.17	38.65	82.1
N(1.5P)K	2	8	9.40	67.51	5.45	27.03	52.82	14.40	32.76	84.5
	5	10	9.03	67.13	5.23	27.62	54.07	13.05	32.87	110.1
NP(1.5K)	2	12	10.33	64.04	4.43	31.51	47.95	11.21	40.82	90.1
	5	6	9.98	64.72	4.83	30.31	51.20	11.74	37.05	97.9
1.5(NPK)	2	15	10.26	64.62	4.99	30.38	47.15	11.58	41.25	79.8
	5	3	9.63	65.85	5.25	28.84	44.24	21.59	34.15	74.5
Manure	1	15	9.82	64.43	5.50	30.01	44.08	18.07	37.84	124.0
	4	3	9.41	65.04	5.42	29.52	42.07	22.29	35.62	97.0

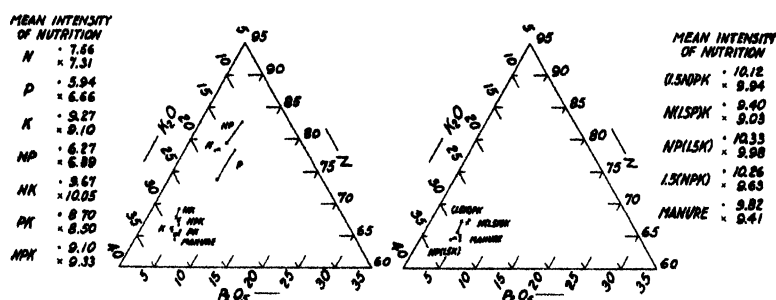


FIG. 6. Graphs showing the mean *NPK-units* of the different treatments, together with the mean intensity of nutrition for the growth cycle. The black spots are for plots in tiers 1 and 2, and the crosses (x) are for their respective duplicates in tiers 4 and 5.

1. *The Relative Positions of the Mean Values of the NPK-units During the Cycle in Relation to that of the Optimum*.—The position of the higher yielding couplet is nearer that of the optimum (manure No. 1–15) except in two couplets ([K] and [NPK]).

In [P], [NP], [NK], [PK], [(1.5N)PK], [N(1.5P)K], and [1.5(NPK)], the displacement of the higher relative to the lower yielding couplet is in the direction of higher  $K_2O$  and lower N in the *NPK-unit* and generally, but not always, *higher intensity of nutrition*.

In the two couplets [N] and [NP(1.5K)] the displacement of the higher relative to the lower yielding couplet is in the direction of higher  $P_2O_5$ , with relatively little difference between the values for N and  $K_2O$ , and with *intensity of nutrition* lower in the higher yielding couplet.

In [K] and [NPK], the two couplets which are abnormal, the mean value of the *NPK-units* during the cycle of the higher yielding duplicate is further from the optimum *NPK-unit* than that of the lower. In one of these couplets [NPK] the yields of the duplicates are so nearly alike that any attempt at analysis loses its significance. But the results suggest that foliar diagnosis is a better indicator of nutritional differences than are yields.

The problem is to explain the anomalous positions of the mean *NPK-units* of the [K] couplets, which in this as in all our experiments on these plots show mean values of the *NPK-units* and of the *intensities* relatively very close together, although the yields differ considerably. Two explanations are possible, but further work is necessary to determine which, if either, is the true one. (a) Either the very great differences in the displacements of the  $\text{N-P}_2\text{O}_5\text{-K}_2\text{O}$  equilibrium from one sampling date to another of the [K] couplets are not truly reflected in mean values; or (b) Some other factor such as the equilibrium between  $\text{CaO-MgO-K}_2\text{O}$  is the controlling one affecting the yields of these plots.

There can be little doubt that great divergence between the values of the mean *NPK-units* of similarly treated plots are associated with the  $\text{CaO-MgO-K}_2\text{O}$  equilibrium. Thus the two couplets [P] and [NP] treated with superphosphate without potash which in this, as in all our earlier experiments, show the greatest divergence between the values of the *NPK-units*, are associated with abnormally high CaO in proportion to the  $\text{K}_2\text{O}$  in the *Ca Mg K-unit* (Table III, column 5) and with wide differences in the relative values of MgO to CaO and  $\text{K}_2\text{O}$ .

#### SUMMARY

Foliar diagnosis is defined as the composition of a leaf taken from a predetermined position (*i.e.* of a definite physiological age) on the plant at the moment of sampling. The foliar diagnosis during a season's growth cycle will then consist of a sequence of chemical states indicative of the nutrition during that cycle for the particular plant species and variety examined. It is pointed out that foliar diagnosis is a more logical basis for fertilizer practice than is the traditional one which relates development and yield to the fertilizer applied, because the relation of yields to nutrition during the growth cycle is more direct than to the fertilizer applied.

In a long-continued field experiment with potatoes (variety Rural Russet) containing plots treated with single "elements", combinations of two elements, and also combinations of all three elements nitrogen, phosphoric acid, and potash, plants from similarly treated couplets were examined by this method. Certain of these plots had been subjected to erosion influences leaving sub-surface clay exposed. This factor and native soil heterogeneity was indicated by relative yields of couplets which differed through a range from 0.9 to 45.3 per cent.

Improved development accompanied by greater yields was obtained when all three "entities" (elements) were applied, findings which generally hold for the Hagerstown soil series.

The foliar diagnosis of plots receiving different treatments indicate

that the presence of nitrogen, of phosphoric acid, and also of potash in the fertilizer is reflected by an increased content of the element in the leaf of plants receiving applications of the particular element. There is, however, no direct relationship between the content of nitrogen in the leaf and the yields from different treatments, nor between the presence of this element in the fertilizer and the yield. The effect of nitrogen on yield is governed by the presence of the others and is readily determined from a consideration of the manner in which the various fertilizer treatments intervene in their effect on the intensity of nutrition and on the composition of the *NPK-unit* (1), in which the changes throughout the cycle are indicated in detail.

A relationship exists between the content of phosphoric acid and also of potash in the leaf and the yields from the different treatments. But no relationship is evident between the presence of these entities in the fertilizer and the yield except when each is accompanied by the other.

Potash is the dominant factor leading to increased *intensity of nutrition*. A low *intensity of nutrition* is always associated with low yields; but owing to the phenomenon of "luxuskonsumption" of potassium, high intensities are not necessarily associated with high yields, although high yields are always associated with adequate intensity.

The course of nutrition with respect to nitrogen, phosphoric acid and potash during the growth cycle is described in detail, with the aid of graphs, for each of the fertilizer treatments; the graphs show in trilinear co-ordinates the equilibrium between  $N-P_2O_5-K_2O$  in the chosen leaf at each date of sampling.

The effect of the various treatments in their relation to yields is more easily described by considering the mean values of the *intensities* and the mean values of the *NPK-units* during the cycle for a particular treatment. In relation to the optimum yield (manure) the mean values of the *NPK-units* during the cycle of the following are too high in nitrogen and too low in potash in both couplets, *viz.*, [N], [P], [NP], [K], [NK], [NPK], [PK], [(1.5N)PK], and [N(1.5P)K]. The first three are abnormally high in nitrogen and abnormally low in potash. In [P], the relative proportion of  $P_2O_5$  is too high in both couplets in relation to the optimum, and in [NPK], [NK], [K], and [1.5N(PK)] it is too low.

The mean value of the *NPK-units* of the higher yielding couplet during the cycle is nearer to the position of the optimum except in two couplets. In seven of these couplets, higher  $K_2O$  and lower N in the *NPK-unit* and generally but not always higher *intensity of nutrition* are associated with the higher yielding couplet; in two couplets the higher yield is associated with higher  $P_2O_5$ , with relatively little difference between the values for N and  $K_2O$ .

Although all plots were limed to approximately the same pH, there exists a marked difference in the foliar diagnosis with respect to

calcium. Moreover, the graphs for calcium are highest in those plots which received superphosphate without potash, indicating the efficiency of superphosphate as a source of calcium for plants.

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## The Effect of Length of Dormant Period of Seed Irish Potatoes on Yield

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THAT the length of dormant period of seed Irish potatoes has a marked effect on many characters of plant growth is well known. Bushnell (1) showed that multiple sprouting of seed pieces was influenced by the storage period. The longer the storage period used the greater the number of sprouts produced. Miller (2) found that the production of flowers on potato plants was greatly affected by the length of dormant period of the seed potatoes. The longer the dormant period the less likely were flowers to be produced. The type of plant growth and maturity were also influenced by the period of dormancy.

In connection with studies on the storage of Irish potatoes at the Louisiana Experiment Station, the effect of length of dormant period on the yields produced by several varieties is being determined. Comparisons are made of yields produced from northern grown certified seed potatoes, those from spring-grown Louisiana potatoes kept in cold storage at 40 degrees F, and yields of fall-grown Louisiana potatoes kept at room temperature from digging time until planting time. Louisiana-grown potatoes that were to be used for seed were grown from northern seed, and the plants were carefully rogued to reduce disease to a minimum. Single row plots 40 feet long, replicated five times, were used in the experiment. Size alone was used as the basis of grade.

Plants from Louisiana spring-grown seed sprouted and grew off rapidly, but were not as vigorous and also matured sooner than those from northern seed. Louisiana fall-grown seed was slower to sprout than that from the North, and both produced vigorous plants. Plants from the former seed source were more upright in growth and matured later than the latter. The growth habits as affected by length of dormancy were consistent and distinct, being very evident after the first few weeks of growth. To date it has been impossible to stimulate growth of plants from Louisiana spring-grown seed so that it more nearly simulates that of plants from good northern seed. Higher storage temperatures stimulated more rapid germination of fall-grown seed.

Yield results obtained are given in Table I. The data show that the yield was greatly influenced by the length of dormancy of the seed from which the crop was produced. Yields were affected to some extent by seasonal conditions, as shown by variations from year to year, but in no case did the production from Louisiana spring-grown seed equal that from northern seed. With the exception of the Katahdin variety, the average yields from spring-grown Louisiana seed were so low that this type of seed cannot be recommended at the present time.

The behavior of the Katahdin variety is especially interesting. Decidedly better results were obtained from Louisiana spring-grown seed with this variety than with any of the other three varieties used in



TABLE I—YIELDS OF FOUR VARIETIES OF IRISH POTATOES AS AFFECTED BY THE LENGTH OF DORMANT PERIOD OF THE SEED FROM WHICH THEY WERE PRODUCED (BUSHELS PER ACRE)

Seed Source	Approximate Period of Dormancy	Katahdin			Chippewa		
		No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
<i>1936</i>							
Northern grown . . . . .	5	278.8	18.6	7.1	260.6	22.7	8.0
Louisiana spring grown . . . . .	9	266.8	28.3	6.0	151.4	37.0	14.4
<i>1937</i>							
Northern grown . . . . .	5	218.2	30.1	11.6	184.8	46.9	17.1
Louisiana spring grown . . . . .	9	164.6	43.2	14.5	78.6	29.8	17.3
Louisiana fall grown . . . . .	3	164.5	22.8	9.8	179.5	18.6	8.2
<i>1938</i>							
Northern grown . . . . .	5	264.2	25.4	9.2	209.5	22.9	9.3
Louisiana spring grown . . . . .	9	230.1	26.5	9.7	64.8	19.6	14.6
Louisiana fall grown . . . . .	3	182.2	18.0	8.4	164.5	11.7	7.0
<i>Average</i>							
Northern grown . . . . .	5	253.7 *	23.7	9.3	218.3	30.8	11.5
Louisiana spring grown . . . . .	9	220.5	32.3	10.1	98.3	28.8	15.4
Louisiana fall grown . . . . .	3	173.3	20.4	9.1	172.0	15.1	7.6
		Houma			Triumph		
		No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
<i>1936</i>							
Northern grown . . . . .	5	249.0	48.3	14.0	258.0	34.0	9.4
Louisiana spring grown . . . . .	9	154.5	37.8	14.4	192.1	36.9	10.8
<i>1937</i>							
Northern grown . . . . .	5	212.7	59.1	27.7	178.3	52.1	20.1
Louisiana spring grown . . . . .	9	81.6	44.4	19.8	84.0	46.9	19.5
Louisiana fall grown . . . . .	3	160.3	34.2	14.5	179.3	37.3	17.5
<i>1938</i>							
Northern grown . . . . .	5	187.9	47.4	21.3	162.3	46.7	18.0
Louisiana spring grown . . . . .	9	94.2	23.8	10.7	73.6	43.8	17.6
Louisiana fall grown . . . . .	3	71.5	33.9	14.9	86.5	32.2	15.3
<i>Average</i>							
Northern grown . . . . .	5	216.5	51.6	21.3	199.5	44.3	15.8
Louisiana spring grown . . . . .	9	110.1	35.3	15.0	116.6	42.5	18.0
Louisiana fall grown . . . . .	3	115.9	34.0	14.7	132.9	34.7	16.4

\*Differences in yield of potatoes produced by northern grown and Louisiana spring-grown seed of the Katahdin variety were highly significant. With the other varieties, differences in yield were even more significant.

this experiment. While not quite equal to those from northern seed, good yields were produced. It should be mentioned also that potatoes from the Louisiana spring-grown seed matured at about the same time as those from northern-grown Triumph seed. This is of importance so far as the early market is concerned. The 3-year average yield of long dormant period Katahdin potatoes was superior to that of the northern certified Triumph seed. No explanation is offered yet as to why the behavior of Katahdin variety differed from that of other varieties tested, but it does not seem to be a matter of rest period. The fact that the Katahdin behaves as it does indicates the probability of breeding varieties so well adapted to the South that spring-grown stored seed may be recommended for planting the following spring. When this is

done the South will cease to be almost entirely dependent on other sections of the country for good seed potatoes.

Only 2 years' results with fall-grown seed are presented. Yields for 1 year were consistently fairly good, while for the other year they were not good for two of the varieties tested. One fault of using fall-grown potatoes for seed the following spring is the difficulty of producing a crop in the fall. Dry weather may reduce yields from the earlier plantings, and an early freeze may cut down the later plantings before they mature. A very good fall crop was produced to be used for seed in 1937 but an early freeze made it necessary to dig very immature potatoes to be planted in 1938. Planting fall-grown potatoes that have been kept at high temperatures from digging until planting time seems to be a very promising source of seed to be used to plant a portion of the spring crop. Potatoes from this source of seed will usually mature later than those from northern certified seed.

The length of the dormant period of seed Irish potatoes plays an important part in the character of growth of plants and yield produced. The effect will vary to some extent with storage conditions. For best results the dormant period should be long enough for the seed pieces to sprout rapidly when planted and the resultant plants to grow vigorously, but not long enough to produce multiple sprouting and stunted early maturing plants.

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# Various Sources of Nitrogen for Potato and Spinach Production on Long Island

By P. H. WESSELS and R. H. WHITE-STEVENS, *Long Island  
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**E**XPERIMENTS have shown that fertilizers are essential for the successful production of commercial crops of vegetables under Long Island conditions. The source of the nitrogen is an important factor in determining the cost of these fertilizers. Many growers believe that certain sources of nitrogen are superior for crop production and are willing to pay a higher price for fertilizers that contain materials such as fish and animal tankage. The nitrogen in these materials costs from two to three times as much as it does in nitrate of soda, sulphate of ammonia, urea or cyanamid. If crop yields can be maintained through the use of these less expensive nitrogenous materials, substantial reductions can be made in the cost of the fertilizers used on many Long Island farms.

An experiment to determine the effect of various sources of nitrogen on the yield of potatoes was conducted at the Long Island Vegetable Research Farm in 1935, 1936, and 1937. The experiment was continued with spinach in 1938 and a study made of the effects of the source of nitrogen on the yield, quality and time of maturity of this crop.

## EXPERIMENT

The experiment was conducted on a level field of Sassafras silt loam soil at the Long Island Vegetable Research Farm. The 12 fertilizer treatments shown in Table I were applied by hand to 48 plots of 1/100-acre each. The four plots of each treatment were so arranged that each treatment was adjacent to each of the other treatments somewhere in the field. This was done to facilitate comparison of differences in type of growth or color of foliage that might result from the different fertilizer treatments.

Each plot contained three rows of potatoes. Irish Cobbler potatoes were used for this experiment because previous work had shown that the nitrogen requirements of this variety is somewhat higher than that of the Green Mountain, the only other variety of potato grown extensively on Long Island. Each plot row received a weighed quantity of fertilizer equivalent to 2,000 pounds of a 5-8-5 fertilizer per acre. Furrows were opened for each row, the weighed quantities of fertilizer distributed in these furrows by hand and the fertilizer mixed with the soil by drawing the marker through the furrows a second time. The seed pieces were then placed in the furrows by hand and covered by machine. All fertilizer treatments except cyanamid were applied the day the potatoes were planted. The cyanamid was applied in the row and mixed with the soil 2 weeks prior to the planting of the potatoes as is recommended by the manufacturers. The rows were spaced 33

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inches apart; the seed pieces were placed 12 inches apart in the row. Cultivation and spraying were given when needed. The potatoes were dug after the crop had matured and all vines were dead. The potatoes were sorted over a mechanical grader with circular openings  $1\frac{1}{2}$  inches in diameter.

The results were analysed by analysis of variance by row and by plot but as the results obtained were essentially the same the yields per acre based on entire plot yields for the 3 year period together with the differences necessary for significance at the 5 per cent point are given in Table I.

TABLE I—YIELDS OF MARKETABLE IRISH COBBLER POTATOES WITH NITROGEN SUPPLIED IN VARIOUS SOURCES

Source of Nitrogen	Yields (Bushels Per Acre)					
	N (Per Cent)	Cost per Unit*	1935	1936	1937	Average (1935 to 1937)
Sodium nitrate	16	1.94	273	218	272	254
Ammonium nitrate	18	—	284	233	288	268
Ammonium sulphate	20.5	1.46	278	217	276	257
Cyanamid	21	1.55	301	214	256	257
Urea	46	2.39	283	230	266	260
Castor pomace	5.5	4.09	278	221	278	259
Cottonseed meal	6.2	—	273	222	275	257
Animal tankage	8.2	3.78	297	231	285	271
Fish scrap	9.0	5.89	281	235	296	271
Mixture $\frac{1}{2}$ each of cyanamid and ammonium sulphate	—	1.50	265	222	263	250
Mixture $\frac{1}{2}$ each of sodium nitrate, ammonium sulphate, and fish scrap	—	3.10	290	220	285	265
Mixture $\frac{1}{2}$ each of sodium nitrate, ammonium sulphate, and castor pomace	—	2.50	297	220	302	273
Difference necessary for significance 5 per cent point	—	—	60	49	74	73

\*Prices obtained through courtesy of Mr. A. M. Eno, G. L. F. Soil Building, New York.

The results indicate that no significant difference in any year or over the 3 year period was found to occur between any of the nitrogen sources employed.

Soil samples were taken on all the plots at various times during the season and tested for nitrates and ammonia by the Morgan method (1). At no time was the nitrate nitrogen in the plowed soil low enough to be considered deficient. Even after a rainfall of 4.73 inches on June 14, 1936 the nitrate nitrogen was present on all plots in quantities deemed sufficient for normal growth and no symptoms of nitrogen deficiency were observed in the plants. Applying the fertilizer in the row and ridging the soil over the rows in cultivating may have prevented severe leaching of the nitrate nitrogen.

In this experiment no single source of nitrogen or combination of two or more sources of nitrogen proved superior. It is probable that the quantity of nitrogen, 100 pounds per acre, was a factor in obtaining this result. Used in such quantities each material was able to supply sufficient nitrogen for the crop regardless of any differences in the rates at which the nitrogen became available. Differences in crop yields with these various sources of nitrogen might appear if the quantity of nitro-

gen applied approached the limiting value for the crop on any specific soil type. The purpose of this experiment was to determine whether less expensive nitrogenous materials could replace the more expensive forms in Long Island potato fertilizers so the quantity of nitrogen was purposely chosen as that commonly applied for Irish Cobbler potatoes on Long Island.

The potato is a comparatively slow growing plant in its early stages. Here on Long Island fertilizer is applied and the potatoes planted in March or early April. Rapid growth does not begin until around the end of May or early in June. With such a long period between the application of fertilizer and the time when the crop begins rapid growth differences in the availability of the nitrogen in the various sources might not manifest themselves in crop response. It was therefore decided to conduct a similar experiment upon a faster growing crop and to employ a nitrogen nutrition level below that found in previous work to be optimum for that crop. Long Standing Bloomsdale spinach was therefore sown on these plots in 1938.

Spring spinach on Long Island has been found to require 90 pounds of available nitrogen per acre for maximum development. In this experiment only 60 pounds of nitrogen per acre was applied. The same plots were employed as for potatoes but because some additional sources of nitrogen were included, a few of the plot treatments had to be rearranged and the replications reduced to three in all cases.

Hydrated lime was applied at the rate of 1 ton per acre to bring the soil to a reaction suitable for spinach, *viz.*, pH 6.2 to 6.6. The spinach was sown in rows 1 foot apart and thinned to 4 inches apart in the row.

To determine the relative rates of growth effected by the various nitrogen sources the crop was harvested at periodical intervals during the growing season. These periodical harvests and the final marketable yields are given in Table II.

TABLE II—YIELDS OF SPINACH AT PERIODIC INTERVALS OF GROWTH IN RESPONSE TO DIFFERENT SOURCES OF NITROGEN (DATA IN BUSHELS PER ACRE, 30 POUNDS PER BUSHEL, ONLY FOURTH HARVEST U. S. No. 1)

Source of Nitrogen	Time of Harvest (Days From Seeding)			
	41	48	54	63
Sodium nitrate	70.84	217.56	448.28	871.61
Ammonium nitrate	50.33	155.04	312.22	646.02
Ammonium sulphate	52.07	136.07	286.46	666.61
Cyanamid	45.49	128.14	324.60	646.35
Urea	45.48	134.14	320.93	617.45
Uramon	39.10	142.46	246.01	598.96
Calnitro	62.90	193.18	433.96	809.18
Ammophos	58.64	163.37	361.96	735.18
Castor pomace	55.55	136.27	315.12	738.14
Fish Scrap	49.94	136.07	276.41	698.44
Tankage	57.88	180.40	373.38	791.87
Cottonseed	38.90	134.52	324.98	652.03
Sodium nitrate + castor pomace	52.45	162.20	321.89	774.32
Sodium nitrate + fish scrap	45.49	150.20	327.70	741.49
Sodium nitrate + tankage	77.04	217.75	469.97	788.30
Sodium nitrate + cottonseed	66.19	225.30	460.09	882.13
Difference necessary for significance at 5 per cent point.	20.65	68.09	122.76	181.76

From this data it is quite apparent that some differences in yield developed as a result of the various nitrogen sources employed.

Sodium nitrate, calnitro and ammophos were equally as good and in some cases better than the other sources employed. Fish scrap and cotton seed meal were inferior to sodium nitrate although when used with sodium nitrate the mixtures were as effective as the nitrate alone.

When the nitrogen applied is reduced below the optimum for spring spinach on Long Island, sodium nitrate is more effective than fish scrap, cottonseed meal, ammonium sulphate, ammonium nitrate, cyanamid, urea, or uramon.

There are comparatively little differential growth affected by the various sources of nitrogen in the rate of development of the crop; the superior sources tended to maintain their superiority throughout the growing period.

### DISCUSSION

The results obtained in these experiments show that when nitrogen is supplied in adequate quantity for potatoes the source of the nitrogen is not an important factor in crop yield where the effect of the nitrogen carrier on soil reaction is avoided. A fast growing crop such as spring spinach shows a differential response to various sources of nitrogen but neither spring spinach nor potatoes indicated that the more expensive sources of nitrogen were superior for crop production. Where a soil is maintained at a reaction suited to the crop the nitrogen may well be supplied in sodium nitrate, ammonium sulphate, urea, uramon, ammophos or cyanamid and the quantity of such materials as cottonseed meal, castor pomace, animal tankage and fish scrap be limited to that needed to give proper mechanical condition to the fertilizer.

### SUMMARY

Data are presented to show that nine different sources of nitrogen and three mixtures of two or more of these were tested for their effect on the yield of Irish Cobbler potato and no significant differences in yield were obtained. With spring spinach sodium nitrate and sodium nitrate plus cottonseed meal were superior to fish scrap, ammonium sulphate, cottonseed meal, cyanamid, ammonium nitrate, urea, and uramon. Calnitro was superior to urea and uramon. In general the cost of the nitrogen in the different materials was no index of its value for crop production. Growers can effect economics in their fertilizer costs by using the less expensive sources of nitrogen.

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# Relation of Mineral Nutrition to Chemical Composition and Cooking Quality of Potatoes<sup>1</sup>

By ORA SMITH and L. B. NASH, *Cornell University, Ithaca, N. Y.*

**T**HIS study was undertaken for the purpose of growing potatoes under controlled nutrient conditions and correlating these conditions with the chemical composition and cooking quality of the potatoes.

One of the principal reasons for the great amount of conflicting data and results concerning cooking quality is that in most instances the potatoes were not grown under controlled or known conditions. In this work the results were obtained from potatoes grown in the greenhouse in sand cultures with complete nutrient solutions and solutions in which one or more elements had been reduced in concentration. In a previous paper (3) results of a similar study were presented. In that experiment the effect of each minor element was determined by completely omitting it from the nutrient solution. The resulting plants and tubers were so abnormal and small that the determination of chemical composition and cooking quality was of little practical value. In this work it was not desired to have absolute deficiencies of any given element but only to lower its concentration sufficiently so that plant growth would be retarded somewhat and deficiency symptoms shown by the plant.

The complete nutrient solution contained the following salts:  $\text{KH}_2\text{PO}_4$ ,  $\text{Ca}(\text{NO}_3)_2$ ,  $\text{MgSO}_4$ ,  $\text{CaCl}_2$ ,  $\text{MnSO}_4$ ,  $\text{Na}_2\text{B}_4\text{O}_7$ ,  $\text{FeSO}_4$ , and  $\text{ZnSO}_4$ . Nitrogen, phosphorus, and potassium were applied in .0052 M, .018 M, and .018 M concentrations, respectively. Low nitrogen, medium potassium, and low potassium were applied in .0013 M, .0017 M, and .0009 M concentrations, respectively. In all solutions, except those in which the minor elements were absent, they were supplied in the following concentrations: magnesium .015 M, manganese 10 parts per million, iron 10 parts, copper 2.5 parts, and boron 0.5 part.

The experiment was set up in four groups. Group I, treatments were planted on March 10, and were complete; high potassium, with low nitrogen; low potassium, with high nitrogen; low potassium, with low nitrogen; low manganese; low copper; low calcium; and low boron. Group II treatments were planted on April 1 and comprised: complete; low copper; low magnesium; and low boron. Group III treatments were planted June 12, and consisted of: complete; low potassium; low calcium; low manganese; and low iron. Group IV, planted July 15 had high potassium; medium potassium; and low potassium. All plants were harvested October 21.

Each treatment in group I consisted of nine plants grown in a section of greenhouse bench filled with washed quartz sand. In groups II and III the treatments consisted of five pots each. Paraffined 12-inch pots were used. In group IV there were six pots in each treatment, three groups of two plants each were taken for chemical analysis and cooking tests.

<sup>1</sup>Paper No. 188, Department of Vegetable Crops, Cornell University, Ithaca, New York.

Certified, small, whole, uniform size tubers of Smooth Rural variety were used for seed. As far as possible the deficient plants were allowed to achieve a medium amount of growth to insure a utilizable amount and good size of tubers. The cultures low in boron, copper, magnesium, manganese, and iron were watered twice early in the growing period with complete solution. At all other times either distilled water or a solution deficient in the one element was added. At intervals of 7 to 10 days each pot was leached thoroughly with distilled water. This leaching prevented the accumulation of certain ions in the culture which might have decreased the balance of the solution.

### RESULTS

The low calcium and low boron cultures were slower to come up than any of the others. The retarding effect of low calcium was very pronounced. In several of the treatments nutrient deficiency symptoms were shown. There was some resemblance between the calcium and boron deficiency symptoms but not great enough to prevent differentiation between the two.

Deficiency symptoms were also observed in low magnesium, low potassium and low copper cultures. A few of the tubers from the low boron cultures showed a breakdown at the stem end with the broken-down tissue having a jelly-like consistency. A similar breakdown was noted in a few tubers from low calcium cultures.

About one-third to one-half of the tubers from low potassium treatments showed internal brown spots or brown specking. Tubers from low calcium cultures also showed some internal breakdown but of a markedly different nature. The breakdown caused by low calcium is more complete and the affected spots larger than those due to potassium deficiency. Some breakdown was noted in the tubers from low magnesium, low copper, low iron, and low manganese cultures but no consistent differences were observed.

The results of chemical analyses of the tubers are presented in Table I.

In most instances the deficiency of an element caused increases in total sugars, starch, tyrosine, and tryptophane. In most cases low or medium potassium concentrations caused increases in starch, alpha amino nitrogen, tyrosine, and tryptophane. Manganese deficiency caused reductions in total sugars and starch and increase in tyrosine. The very low starch and high nitrogen content of tubers in group I may be related to the fact that the plants in this experiment were alive and growing for a much longer time than the plants in the other cultures and it is probable that during this longer period more nitrate was absorbed and accumulated in the tubers in the form of protein which would be formed at the expense of carbohydrates. This explanation seems logical in view of the fact that the nitrogen content decreased and starch content increased with a shortening of the growing period.

The ratio of protein ( $N \times 6.25$ ) to starch, taking the groups as a whole, was in the order  $IV > III > II > I$ , caused by a decrease in starch



TABLE I—PER CENT COMPOSITION OF DRY WEIGHT OF TUBERS GROWN IN VARIOUS NUTRIENT SOLUTIONS

Treatment	Total Sugars	Starch	Total Nitrogen	Ratio Protein to Starch	Alpha Amino Nitrogen	Tyrosine	Tryptophane
<i>Group I</i>							
Complete	0.70	56.85	2.30	1:3.9	.702	.064	.013
High K, low N	2.09	59.34	1.43	1:6.6	.389	.040	.012
Low K, high N	1.77	56.43	1.94	1:4.7	.491	.067	.024
Low K, low N	2.68	59.21	1.30	1:6.5	.325	.078	.015
Low manganese	0.68	54.45	2.20	1:4.0	.684	.095	.006
Low copper	0.26	57.06	2.40	1:3.8	—	.059	.021
Low calcium	1.34	56.46	2.24	1:4.0	.483	.102	.012
Low boron	2.24	54.30	2.23	1:3.9	—	.080	.007
<i>Group II</i>							
Complete	1.29	63.35	2.01	1:5.0	.518	.063	.012
Low copper	1.91	65.00	1.71	1:5.1	—	.073	.017
Low magnesium	1.17	61.72	2.08	1:4.8	.542	.069	.010
Low boron	1.28	63.98	1.87	1:5.5	.590	.119	.011
<i>Group III</i>							
Complete	1.35	64.49	1.83	1:5.6	.413	.045	.007
Low potassium	1.15	70.29	1.69	1:6.7	.610	.077	.010
Low calcium	1.55	69.67	1.45	1:7.7	.362	.058	.008
Low manganese	0.88	58.70	1.88	1:5.8	.505	.073	.011
Low iron	1.52	67.85	2.03	1:4.6	.664	.094	.014
<i>Group IV</i>							
High K	1.19	66.41	1.61	1:6.6	.523	.073	.012
High K	1.17	66.13	1.66	1:6.1	.596	.119	.009
High K	1.32	65.95	1.67	1:6.3	.527	.092	.010
Medium K	1.31	66.66	1.91	1:5.6	.794	.171	.024
Medium K	1.12	70.44	1.56	1:7.2	.432	.096	.011
Medium K	1.35	72.52	1.66	1:7.0	.650	.105	.010
Low K	1.27	67.97	1.70	1:6.4	.699	.128	.014
Low K	1.20	67.22	1.81	1:5.9	.754	.177	.032
Low K	1.28	69.42	1.68	1:6.6	.649	.154	.017

and an increase in nitrogen with the longer growing seasons. Within the groups the differences in ratios were seldom great.

With these differences in sugar, starch, nitrogen, protein-starch ratio, alpha amino nitrogen, tyrosine and tryptophane one might expect differences also in cooking quality. Tubers of each of the treatments were subjected to standard boiling tests in the Department of Foods and Nutrition of the College of Home Economics. The results of these cooking tests as a whole do not show any consistent differences. There are two relationships which should be pointed out, however, (a) the only darkening observed was in a sample grown in a low potassium culture. The deficiency of potassium as a cause of blackening has been discussed by Nagy (2). In the low potassium tubers the per cent of amino acids and particularly tyrosine and tryptophane were found to be higher. The blackening of tubers has been fairly definitely associated with the reaction involving the oxidation of tyrosine to melanin. Also it has been shown by Hartt (1) that low potassium either decreases the stability of proteins or hinders their formation in plants. (b) The per cent of starch and the protein-starch ratio apparently do not affect

the mealiness of the potatoes. In group 1 the tubers had the lowest per cent starch (15 per cent lower in some cases) and the highest protein-starch ratio and yet were as mealy as the others.

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## Effects of Certain Chemicals on Apical Dominance and Rest Period of Russet Burbank Potatoes<sup>1</sup>

By GEORGE W. WOODBURY, *University of Idaho, Moscow, Ia.*

**I**N potato seed production it seems desirable to promote growth of a maximum number of shoots from a seed piece in order to insure the development of a fair number of medium sized tubers per hill. The phenomenon of apical dominance frequently results in a small number of shoots per hill accompanied by the production of a limited number of good sized tubers somewhat above the accepted size for seed use.

Apical dominance in the potato (*Solanum tuberosum*) has been noted and studied by many investigators (1, 2) in the field. According to Denny (2), the tubers of most varieties of potatoes exhibit apical dominance or the ability of the apical bud to prevent the growth of basal buds. Several theories have been advanced as to the cause of this phenomenon. The work of Denny (2) with Bliss Triumph potatoes demonstrated the possibility of the suppression of apical dominance by use of various chemicals; notably thioruea and potassium thiocyanate. Tubers treated with various aqueous solutions of these chemicals also exhibited marked tendency toward multiple sprouting.

Denny and Miller (3) found that sodium thiocyanate and ethylene chlorohydrin were effective in breaking the rest period of tubers stored for short periods after harvest.

With the idea of suppressing apical dominance and of making multiple sprouting applicable to field conditions, experiments were set up in the University greenhouse during the winter of 1937-38 and continued in the field during the summer. Russet Burbank, the variety frequently spoken of as Idaho Russet and as Idaho Gem, as well as Netted Gem, was used. This variety seems to be somewhat slower in completing its rest period than do some of the other commercial varieties. Tubers taken from storage during late fall and early winter sprout very slowly when placed under growing conditions, making the work of tuber-indexing in the greenhouse somewhat difficult until late winter or early spring.

As nearly as possible, the tubers used in this work were kept at approximately three different storage temperatures. Common storage at the University cellar averages between 40 and 45 degrees F during winter and early spring months. Commercial cold storage obtained locally should average somewhat below this; probably about 32 to 36 degrees F. A 50 degrees F storage was arranged by providing additional heat in a common storage. It might be stated here that the cold storage which was rented probably was not kept as cold as had been expected; temperatures ranging between 35 and 45 degrees F.

At regular intervals tubers were taken from each storage and prepared for planting. Uniform tubers, averaging from 2 to 2½ ounces were selected. In some instances, potatoes were halved longitudinally, with halves of identical tubers being used for different treatments. No

<sup>1</sup>Published with the approval of the Director of the Idaho Agricultural Experiment Station as Research Paper No. 177.

whole tubers were used in any of the series. Each series was treated as follows: Lot 1, soaked in 4 per cent solution of thiourea ( $\text{NH}_2\text{CSNH}_2$ ) 1 hour; Lot 2, soaked in 4 per cent potassium thiocyanate (KSCN) 1 hour; Lot 3, no treatment. After treatment, tubers were planted and grown under greenhouse conditions in pots.

The earlier plantings exhibited marked differences between the treated and untreated plots, not only in the number of sprouts pro-



FIG. 1. Upper tubers given no treatment. Center, treated with 4 per cent thiourea 1 hour. Bottom, treated with 4 per cent KSCN 1 hour. Tuber halves in upper two pictures taken from identical tubers.

duced, but in their general vigor as well. Fig. 1 shows three lots of potatoes which were planted January 13, 1938. About a month after planting, tubers were carefully removed from the pots and soil and sand washed from the roots. It will be observed that the treated tubers average about two sprouts per tuber piece. These are not necessarily apical shoots, and are much longer than those on the untreated halves. In this part of the experiment, the untreated pieces were halves of the identical tubers treated with thiourea. The tubers treated with potassium thiocyanate are more vigorous than either of the other two lots. The somewhat rugose appearance of the thiourea-treated lot seemed characteristic throughout the entire series.

Table I shows effects of chemical treatment on apical dominance and the number of shoots pro-

duced by various lots of potatoes. In every case the thiourea treated tubers produced at least double the number of sprouts produced by the untreated lots. The increase in sprouts resulting from the potassium thiocyanate treatment seems to be significant in practically every case. Earlier series exhibited practically the same differences.

To demonstrate the possibility of increasing multiple sprouting in the field by using the treatments outlined above, both thiourea and potassium thiocyanate were used as above on seed potatoes at planting

TABLE I—EFFECTS OF CHEMICAL TREATMENT AND STORAGE ON APICAL DOMINANCE AND SPROUT PRODUCTION IN RUSSET BURBANK POTATOES UNDER GREENHOUSE CONDITIONS (PLANTED MARCH 21, 1938, RECORDS TAKEN APRIL 24, 1938)

Storage Treatment	Number of Sprouts per 10 Tubers			
	KSCN	Thiourea	Check	Total
Common storage (40 to 45 degrees F) . . . . .	22	27	11	60
Cold storage (35 to 45 degrees F) . . . . .	23	30	15	68
50 degrees storage . . . . .	18	44	14	76

time (June 15). Approximately 1 bushel of Russet Burbank certified seed was used in each treatment. The seed tubers were soaked 1 hour in 4 per cent solutions of each of the two chemicals, cut and planted according to local practice. Yield, average size of tubers, weights per hill and number of stems per hill are shown in Table II.

TABLE II—EFFECTS OF CHEMICAL TREATMENTS ON TUBER PRODUCTION IN RUSSET BURBANK POTATOES

Treatment	Number Hills	Total Number Tubers	Total Number Stems	Total Yield (Pounds)	Average Number Tubers Per Hill	Average Number Stems Per Hill	Average Weight Per Tuber (Ounces)
KSCN . . . . .	230	1,643	932	270	7.14	4.05	2.63
Thiourea . . . . .	227	1,403	890	276	6.18	3.93	3.15
None. . . . .	222	1,304	714	333	5.87	3.21	4.09

While results obtained from the field are not as striking as those obtained under greenhouse conditions, there is a marked tendency toward increased tuber production on both of the treated lots, with an accompanying decrease of tuber size. The tubers grown in the greenhouse were cut before being treated, while those planted in the field were cut after treatment. There is reason to believe that more striking results might be obtained by cutting before treatment.

Denny (2) in discussing practical application of these treatments mentions the high price of thiourea. Present cost of thiourea is about \$2.75 per kilogram as against the former price mentioned by Denny of \$15.00 per kilogram. It is possible also, that a less refined product could be purchased at a lower price.

## CONCLUSION

Russet Burbank potatoes, when treated with 4 per cent aqueous solutions of potassium thiocyanate and thiourea, gave marked increase in sprout production. Evidence of shortening of the rest period was shown in earlier plantings, such differences gradually disappearing until the normal termination of the rest period.

Similar treatments, given to seed potatoes planted in the field, increased the number of stems and tubers per hill with a reduction in

tuber size. Differences in the field corresponding to those obtained under greenhouse conditions might be expected if tubers were cut before treatment as was the case in greenhouse grown material.

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# The Influence of Nitrogen on Grade and Shape of Triumph Sweetpotatoes in Mississippi<sup>1</sup>

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SCHERMERHORN (2) found that the Jersey type of sweetpotatoes tended to produce proportionately longer roots when New Jersey soils were treated excessively with nitrogen fertilizers. He also obtained a decrease in yield of market grades when the nitrogen was increased above 3 to 4 per cent in the fertilizer. Zimmerly (3) working with the Big Stem Jersey variety on eastern shore soils of Virginia found that "the percentage of prime sweetpotatoes based on the total number of enlarged roots was greatest on the plot treated with a 3-3-15 mixture and lowest on the area fertilized with a 3-15-3 formula." He noted a downward trend in yield of primes when the ammonia was increased beyond 6 per cent in the fertilizer. In other experiments Zimmerly (4), working with the Porto Rico variety on Atlantic coastal plains soils of Virginia, found that the L/D ratio increased consistently with few exceptions with increase in length, while there was no consistent decrease in diameter. He also found that where equal  $K_2O$  percentages were compared high  $NH_3$  to low  $P_2O_5$  ratios gave lower L/D ratios, and where equal  $NH_3$  percentages were compared the ratio of high  $K_2O$  to low  $P_2O_5$  gave lower L/D ratios than did high  $P_2O_5$  and low  $K_2O$  combinations. His results indicated that highest yields were associated with lowest L/D ratios, or chunkiness of roots.

The purpose of this paper is to present part of the results obtained from experiments conducted in the vicinity of Laurel, Mississippi during the past 4 years in which the nitrogen content of fertilizers was varied.

## METHODS

In 1935 the work was done on new (cultivated 1 year) Ruston fine sandy loam soil, very old (cultivated about 40 years) Ruston fine sandy loam soil, Orangeburg fine sandy loam soil, and Cahaba fine sandy loam soil. In 1936 the same Cahaba plots were planted as were used in 1935. This land, which was well fertilized, had previously grown truck crops in rotation with legumes, corn, and cotton which were also well fertilized. In 1936 the new Ruston soil was not included. In 1937 and 1938 only Cahaba and old Ruston soils were used. Cotton, corn and legumes had been cultivated for many years on the Orangeburg and old Ruston soils. These soils had been moderately well fertilized annually, receiving 12 to 32 pounds per acre of N, 24 to 64 pounds per acre of  $P_2O_5$ , and 16 to 64 pounds per acre of  $K_2O$ . In 1938 samples of soil were taken from the plowed depth of each plot before applying the fertilizer, and by the use of a Beckman glass electrode the pH was determined. On the Ruston field the pH of the 16 plots in the N group

<sup>1</sup>Contribution from the Department of Horticulture, Mississippi Agricultural Experiment Station, State College, Mississippi. Published with the approval of the Acting Director, Mississippi Agricultural Experiment Station. Paper No. 7, New Series, December 15, 1938.

ranged from 5.11 to 5.74 and averaged 5.51; on the Cahaba field it ranged from 5.69 to 6.20 and averaged 5.96 on the N group of plots. By using Miles (1) rapid test methods the  $\text{NO}_3$ , Ca, Fe, and Mg were found to be low,  $\text{P}_2\text{O}_5$  medium, and  $\text{K}_2\text{O}$  medium to low.

The fertilizers were applied at the rate of 800 pounds per acre, all before setting the plants. Potash was applied at the rate of 4 per cent and phosphorus at 8 per cent on all plots in the N series. The N applied in the various treatments was 2, 4, 6, and 8 per cent. These four treatments were systematically distributed in a Latin square making four replications of each treatment. The resulting plot arrangement was such as would allow in most cases six adjacent paired comparisons of treatments for an analysis of the yield data by the "Student" method.

Plants were spaced 15 inches in the drill in 1935, 18 inches in 1936 and 1938, and 12 inches in 1937 in  $3\frac{1}{2}$  foot rows. The "high ridge" method of land preparation and cultivation was practiced. The Triumph variety was used, and sprouts carefully selected for uniformity were used throughout the studies.

The plots were approximately 0.0072 acre in size, exclusive of guard rows and border spaces, and consisted of 6 rows 15 feet long.

When harvested the roots of each plot were graded on the basis of size only into jumbos, U. S. No. 1's, U. S. No. 2's, and culls, and each grade weighed. The cull size included roots from  $\frac{3}{4}$  to  $1\frac{1}{2}$  inches thick. Such roots, though usually considered as culls, can be utilized for starch manufacture and for that reason are included in the total yields considered here. Measurements for determining shape indices were made from 50 No. 1 roots of each plot on Ruston and Cahaba soils. The roots were chosen at random after the grading and weighing had been completed. The length of the roots was taken as that portion thicker than  $\frac{1}{2}$  inch. The shape index referred to in this paper is the quotient of the length divided by the maximum diameter.

## RESULTS

The data obtained from these experiments as to effect of N on grade are shown in Table I. The percentages shown are not mean figures, but were calculated from the means of the yields of grades in the four plots of a particular year or soil.

A study of the data in Table I fails to reveal any significant influence of nitrogen upon grade. The data show that on Orangeburg soil there was a greater proportion of the crop graded as jumbo than on the other soils. This difference is doubtless due to the fact that the Orangeburg soils were more fertile, contained more organic matter, and were more retentive of moisture than the other two. The data show that there were greater proportions of jumbos on Cahaba soil in 1936 and 1938 than in 1935, and on Ruston soil in 1937 and 1938 than in 1935. This was, no doubt, due to the wider spacing, 18 inches, given to plants in the row in 1936 and 1938, and to a higher residue of nitrogen, as well as a greater organic matter content from winter legumes on the Ruston field in 1937. The spacing effect was not reflected in the Orangeburg soil as it evidently had the capacity to take care of the extra number of plants in the closer, 15 inches, spacing of 1935. It is



TABLE I—EFFECT OF NITROGEN IN FERTILIZER ON PERCENTAGE OF TOTAL YIELD OF SWEETPOTATOES IN EACH GRADE

Year	N in Fertilizer (Per Cent)	Per Cent of Total Yield in Grade Indicated				Total Yield per Acre (Bushels)
		Jumbo (Per Cent)	No. 1 (Per Cent)	No. 2 (Per Cent)	Culls (Per Cent)	
Cahaba Soil						
1935.....	2	1.2	82.7	10.5	5.6	388
1935.....	4	3.9	83.1	8.4	4.6	391
1935.....	6	3.7	83.7	7.7	4.9	401
1935.....	8	5.9	83.4	7.3	3.4	406
1936.....	2	12.4	71.9	11.4	4.3	299
1936.....	4	12.7	73.9	9.5	3.9	346
1936.....	6	9.7	75.8	11.5	3.0	331
1936.....	8	14.5	71.9	8.3	5.3	399
1937.....	2	1.1	86.6	9.0	3.3	277
1937.....	4	0.0	86.2	10.2	3.6	275
1937.....	6	0.0	86.9	10.9	2.2	330
1937.....	8	0.3	87.9	8.6	3.2	316
1938.....	2	15.3	67.3	13.6	3.8	287
1938.....	4	13.3	73.3	8.4	5.0	308
1938.....	6	8.2	75.9	12.6	2.3	316
1938.....	8	8.5	74.1	13.2	4.2	340
Orangeburg Soil						
1935.....	2	13.1	75.7	5.7	5.5	436
1935.....	4	9.6	77.2	6.7	6.6	386
1935.....	6	14.9	73.2	5.3	6.6	374
1935.....	8	16.7	72.5	6.6	4.2	364
1936.....	2	15.3	69.4	9.4	5.9	255
1936.....	4	9.4	76.9	7.2	6.5	264
1936.....	6	17.1	68.8	8.3	5.8	263
1936.....	8	14.2	71.6	8.3	5.9	289
Ruston Soil						
1935*.....	2	2.6	85.2	6.3	5.9	251
1935*.....	4	2.5	82.2	8.5	6.8	247
1935*.....	6	1.5	83.3	8.5	6.7	282
1935*.....	8	5.5	81.1	7.5	5.9	307
1935†.....	2	0.0	83.1	8.0	8.9	225
1935†.....	4	0.0	78.6	11.2	10.2	258
1935†.....	6	0.0	86.8	6.6	6.6	273
1935†.....	8	0.0	86.1	8.4	5.5	286
1936.....	2	1.9	71.7	20.0	6.2	209
1936.....	4	0.0	73.8	18.5	7.7	195
1936.....	6	5.0	80.5	8.0	6.5	225
1936.....	8	3.9	74.0	15.6	6.5	231
1937.....	4	7.9	75.5	10.7	5.9	290
1937.....	6	4.2	79.8	11.3	4.7	283
1937.....	8	8.4	69.7	14.3	7.6	238
1938.....	2	9.6	74.4	12.0	4.0	375
1938.....	4	8.9	73.8	14.4	3.0	382
1938.....	6	11.3	72.9	12.0	3.8	399
1938.....	8	15.5	71.9	10.3	2.3	385

\*New soil.

†Old soil.

notable that in almost every case where an increased proportion of jumbos was found this increase was made at the expense of the No. 1 grade.

The data obtained on shape are presented in Table II. These results fail to show that nitrogen, when varied from 2 to 8 per cent in fertilizers containing moderate quantities of  $P_2O_5$  and  $K_2O$ , has any effect upon the shape of the roots of the Triumph variety. They show, however, that shape is influenced considerably by soil texture. It is noted in Table II that the roots on Cahaba soil were more slender than those on Ruston soil. The Cahaba soils used in these experiments were more sandy and thus more loose and friable than the Ruston soils. It is also noted that the roots on Ruston soils were more slender in 1936 than

TABLE II—SHAPE INDICES OF U. S. NO. 1 SWEETPOTATOES AS INFLUENCED BY NITROGEN IN FERTILIZER

Soil	N in Fertilizer (Per Cent)	1935 (Index)	1936* (Index)	1937 (Index)
Cahaba. . . . .	2	$2.58 \pm 0.064$	—	$3.12 \pm 0.033$
Cahaba. . . . .	4	$2.74 \pm 0.081$	—	$3.11 \pm 0.093$
Cahaba. . . . .	6	$2.78 \pm 0.039$	—	$3.05 \pm 0.056$
Cahaba. . . . .	8	$2.72 \pm 0.067$	—	$3.30 \pm 0.113$
Ruston. . . . .	2	$2.15 \pm 0.016$	$3.04 \pm 0.065$	—
Ruston. . . . .	4	$2.55 \pm 0.092$	$3.09 \pm 0.084$	$2.92 \pm 0.046$
Ruston. . . . .	6	$2.31 \pm 0.038$	$2.82 \pm 0.010$	—
Ruston. . . . .	8	$2.24 \pm 0.051$	$2.88 \pm 0.096$	$2.49 \pm 0.034$

\*Roots on Cahaba soil were not measured in 1936.

in 1935 and 1937. The Ruston soils used in 1935 and 1937 were more clayey, and thus heavier and more easily compacted than the Ruston soils used in 1935.

### CONCLUSION

Under the conditions of these experiments, increasing the N content of the fertilizer from 2 to 8 per cent had no apparent effect on the proportions of the various grades nor on the shape of the roots of sweetpotatoes of the Triumph variety.

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## Low Temperature Injury to Certain Vegetables After Harvest<sup>1 2</sup>

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LOW temperature injury to certain vegetables has frequently been observed when fresh vegetables are exposed to temperatures of 50 degrees F or lower in storage or during transit. This chilling injury, also referred to as pitting or denting, is distinctly different from freezing injury. Vegetables damaged by frost are easily recognized by large, water-soaked areas which penetrate deeply into the tissue. The symptoms of chilling injury, on the other hand, are numerous circular pits on the surface of the fruit. These pits are usually less than 1 millimeter deep and have a diameter of 3 to 10 millimeters. In severe cases, several pits combine to form large, irregular, sunken areas. In cucumbers low temperature injury becomes evident first by a sinking of the spines, which is followed by the formation of depressions in other areas on the surface of the fruit. Since the breakdown is confined to the surface tissue it does not impair the edibility of the vegetable involved. Nevertheless, the market value of pitted fruits is greatly lowered because of their unattractive appearance. Furthermore, the pitting itself is usually followed by the development of pathogenic organisms in the sunken areas.

Rose, Wright, and Whiteman (2) noticed that pitting occurs in cucumbers which have been exposed to temperatures of 32 to 50 degrees F. They also observed the same type of injury from chilling in muskmelons, honey dew melons and watermelons. Several other workers have subsequently described pitting in vegetables and citrus fruit and have confirmed the opinion that pitting is chiefly the result of prolonged exposure to relatively low temperature. Nelson (1), one of the earliest investigators to describe this defect in potatoes, lettuce, and cabbage, recognized the role of low temperature in causing pitting, but showed further that the same type of injury can be produced at room temperatures through the complete or partial exclusion of oxygen. He suggested that the true cause of pitting injury is abnormal respiration, resulting in suboxidation and the formation of toxic substances, which in turn cause a dying of the tissue near the epidermis.

The present study was undertaken after frequent observations had shown that not only does the susceptibility to low temperature injury vary with different kinds of vegetables, but also the severity of pitting in any one kind depends on other factors than temperature alone.

### EXPERIMENTAL DATA

Preliminary experiments had shown that cucumbers held at a temperature of 34 degrees F in a small, closed chamber, which was

<sup>2</sup>Published as Paper No. 182 of the Department of Vegetable Crops, Cornell University, Ithaca, New York.

<sup>1</sup>This study was financed in part through a grant by the Empire State Gas & Electric Association.

ventilated every day, developed less pitting than a comparable lot which was exposed to the normal air of the storage room. This suggested that the high humidity prevailing in the chamber was responsible for reducing the low temperature injury.

An attempt was then made to study the effect of humidity on the severity of pitting. Ten cucumbers each were placed in two chambers

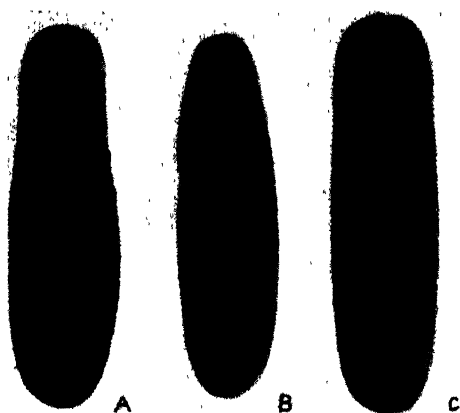


FIG. 1. Effect of relative humidity on severity of pitting in cucumbers after 9 days' storage at a temperature of 32 to 36 degrees F. Per cent relative humidity of storage chambers: A, 90 to 100; B, 70 to 75; and C, 50 to 54.

in a room held at a temperature of 34 degrees F. A slow stream of dry air was passed through the one and of saturated air through the other container. Because of the relatively small air space and the large volume of fruits in the chamber, it was not possible to maintain a relative humidity of less than 70 per cent in the dry chamber. Nevertheless, after 10 days the fruits in the high humidity chamber showed distinctly less pitting than those held in an atmosphere of 70 per cent relative humidity.

A better control of humidity was obtained in a second experiment where 10 cucumbers each were stored in large, galvanized, closed containers of about 130 liter capacity. Calcium chloride in the bottom of one container reduced the relative humidity to an average of 54 per cent. In a second container, a nearly saturated atmosphere was maintained by a shallow layer of water beneath the fruits. A third lot was kept in the open air of the room at an average relative humidity of 73 per cent. The temperature of the room was 34 degrees F  $\pm$  2 degrees. In order to prevent suboxidation in the chambers, they were opened twice daily to allow fresh air to enter. Since the respiration rate at 34 degrees F is very low and since the air space in the chambers was many times that of the cucumbers, it was felt that there was no possibility of a deficiency of oxygen or an accumulation of appreciable quantities of carbon dioxide in the con-

TABLE I—EFFECT OF RELATIVE HUMIDITY ON SHRINKAGE AND SEVERITY OF PITTING IN CUCUMBERS AT A TEMPERATURE OF 32 TO 36 DEGREES F FOR 9 DAYS

Temperature	Relative Humidity (Per Cent)	Shrinkage (Per Cent)	Severity of Pitting
32 to 36 degrees F. ....	50 to 54	4.35	Severe
	70 to 75	2.87	Moderate
	90 to 100	0.51	Very slight

TABLE II—EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON THE SEVERITY OF PITTING OF CUCUMBERS DURING A 7-DAY PERIOD

Temperature	Relative Humidity (Per Cent)	Shrinkage (Per Cent)	Severity of Pitting
39 to 42 degrees F . . . . .	50 to 60	7.89	Severe
	79 to 88	3.75	Moderate
	95 to 100	0.85	None
49 to 50 degrees F . . . . .	50 to 55	9.46	Moderate
	81 to 90	3.29	None
	90 to 100	1.05	None
60 to 61 degrees F. . . . .	50 to 60	12.00	Very slight
	81 to 90	3.41	None
	95 to 100	1.09	None

tainers. The results of this experiment are summarized in Table I and the appearance of the fruits is illustrated in Fig. 1. Again, as in the first experiment, a distinct, inverse correlation was found between the relative humidity and the severity of injury.

Next a more comprehensive experiment was conducted in which different ranges of relative humidity as well as different temperature levels were maintained. Essentially, the same procedure was followed as in the previous experiment.

The results of this study summarized in Table II show conclusively that pitting injury becomes progressively less pronounced as the temperature is raised and also that the severity of pitting can be reduced appreciably by raising the relative humidity of the storage room. A relative humidity of 95 to 100 per cent prevented pitting entirely during a seven day period at temperatures between 40 and 60 degrees F. Even an average humidity of 86 per cent was sufficient to offset the temperature effect at temperatures of 50 and 60 degrees F.

The results of these experiments suggest that the reason why a high

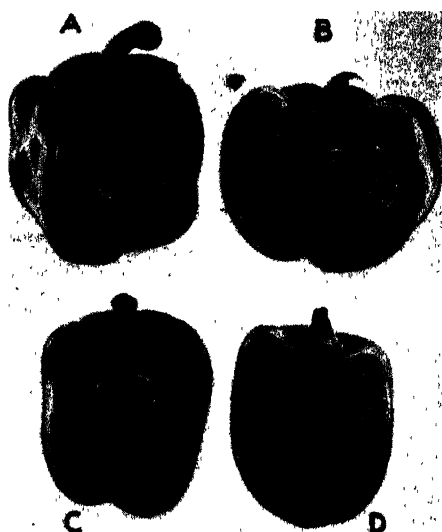


FIG. 2. Effect of relative humidity on development of pitting injury in peppers after 13 days' storage at a temperature of 40 and 60 degrees F. Conditions in the storage chamber from which the fruits were removed:

Temperature (Degrees F)	Relative Humidity (Per Cent)	Condition
A, 40	98 to 100	No injury
B, 40	65 to 75	Severely pitted
C, 60	90 to 100	No injury
D, 60	50 to 60	Shrivelled, not pitted

relative humidity delays pitting is to be sought in its effect on the transpiration rate of the fruits. The data on weight losses through shrinkage (Table II) serve as a reliable index of the transpiration rate and they show that at any one temperature the severity of pitting was directly correlated with the rate of transpiration. On the other hand the results also indicate that even a very rapid rate of water loss did not result in pitting injury, unless the fruits had been exposed to relatively low temperatures at the same time.

Further evidence was obtained to show that the reduced transpiration rate, rather than the high humidity itself, is effective in minimizing the low temperature effect. One lot of cucumbers was coated with a thin film of wax by dipping into an emulsion containing paraffin and carnauba wax. The wax coating reduced the transpiration rate by 45 per cent as compared with a control lot when both were held at a temperature of 33 degrees F and a relative humidity of 70 per cent. An inspection of the fruits after 13 days showed the control group to be injured distinctly more than the waxed one. These findings are also in agreement with the observation that cucumbers grown in the field are less susceptible to pitting at low temperatures than fruits obtained from the greenhouse. On the basis of available data it can be assumed safely that the transpiration rate of greenhouse cucumbers is somewhat higher than that of fruits grown outdoors. It is also significant that pitting is most common in cucumbers, a vegetable which has a higher water content than most others.

A study of the effect of temperature and humidity on peppers of the California Wonder variety gave essentially the same results as were obtained with cucumbers. No pitting was observed at temperatures above 40 degrees F when the relative humidity was 95 per cent. Some injury occurred at 40 and 50 degrees F when the relative humidity

was 55 per cent or less. At 60 degrees F and a relative humidity of 55 per cent the fruits showed severe shriveling but no pitting (Fig. 2).

Further experiments showed that low temperature injury can be produced in eggplants, watermelons, summer squash, winter squash, pumpkin, snap beans, and celery when these vegetables were held in a room at an average temperature of 35 degrees F and a low relative humidity. In some of the vegetables the appearance of the pitted areas was delayed for several weeks.

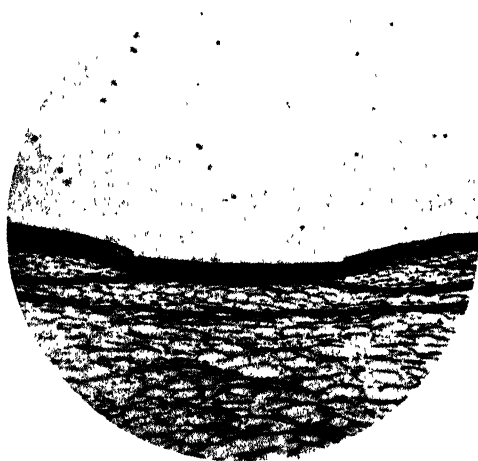


FIG. 3. Transverse section through a pitted area of a cucumber.

Histological studies confirmed the theory that the water relation in the tissue near the epidermis plays an important role in producing pitting injury. Fig. 3 shows that in the affected area the cells in the epidermis have sloughed off entirely and the bordering tissue appears to have lost most of its water content.

It seems obvious, however, that desiccation is not the initial cause of pitting, but is simply the result of injury to certain cells on the epidermis. Primary injury to the cells may be produced by low temperature, mechanical injury or suboxidation. In either case the pitted condition of the fruit comes into appearance whenever the desiccation rate of the injured cells is accelerated by maintaining a low relative humidity. On the other hand, any method which reduces the rate of water loss from the fruit tends to delay or prevent the formation of pitted areas even though some injury has taken place.

The results of this study offer no explanation as to the actual mechanism and the true cause of the initial injury. Additional experiments are under way to study the course of respiration of cucumbers and other vegetables at different temperatures in order to find out whether or not pitting injury is always associated with suboxidation, as suggested by Nelson (1).

In this connection it should be mentioned that it was possible to produce typical pitting in cucumbers even at a temperature of 70 degrees F when the cucumbers were kept for 1 week in a closed container, where the atmosphere was replaced twice daily by introducing pure nitrogen.

#### CONCLUSION

Experimental results are presented to show that low temperature injury, commonly called pitting, may occur in cucumbers at all temperatures between 33 and 60 degrees F. Other conditions being equal, the severity of the injury becomes progressively lessened as the temperature is raised.

The relative humidity of the storage room has a pronounced effect on the rate at which pitted areas form at any one temperature, the severity of pitting being inversely proportional to the relative humidity of the storage atmosphere.

Practically the same results were obtained when peppers were held at various temperatures and under various conditions of relative humidity.

Evidence is produced which indicates that the final stage of low temperature breakdown is a localized desiccation process near the epidermis of the fruit.

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# Effect of Size, Condition, and Production Locality on Germination and Seedling Vigor of Baby Fordhook Bush Lima Bean Seed

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**V**ARIATION in vigor of seedlings and in percentage of germination noted in a preliminary germination test of Baby Fordhook lima bean seed grown in different locations, led to the present study of the relationship between seed size, seed condition, locality and weather conditions in which the seed was produced.

## MATERIALS AND METHODS

Seed from the progeny of a single plant of the Baby Fordhook variety of the bush lima bean was grown for increase purposes during 1937 at Greeley, Colorado; Charleston, South Carolina; and Beltsville, Maryland.

During the maturity and drying period of the seed at Greeley, Colorado, relative humidity was low with no rain, temperatures were moderate and drying was readily accomplished in the field without covers or damage from rain or dew. The seed was harvested on October 1, 1937. At Charleston, South Carolina, the seed matured during the summer when temperatures and humidity were high. It was necessary to strip the first ripening pods from the plant on July 20, 1937, and to dry them in thin layers spread on greenhouse benches in order to prevent sprouting in the pod caused by heavy dews and frequent rainfall (3 weeks later the entire plants were pulled and dried in the greenhouse). At Beltsville, Maryland, the first crop of pods was harvested on August 31 and September 1, 1937, following a period of high temperatures and frequent rainfall. From August 18 to September 1, the daily mean temperatures ranged from 65.5 degrees to 83 degrees F with an average mean temperature of 76 degrees F. During this period 5.27 inches of rain fell in 7 days. These pods were spread in the greenhouse under air movement from fans to dry. A large percentage of this first harvest had sprouted or rotted in the pod and many seeds were slightly pitted or weather spotted. The entire plants were pulled on September 15 after the majority of the remaining pods had turned yellow or brown and dried rapidly in the greenhouse. The daily mean temperatures from September 2 to 16 ranged from 58.5 to 79 degrees F with an average mean of 68 degrees F. A total of 0.51 inch of rain fell in 3 days during the 1st third of this period.

The seed was removed from the pods by treading on canvas sheets or by hand flailing, at all locations.

The Beltsville, Maryland; Charleston, South Carolina; and Greeley, Colorado, seed was stored at Beltsville in a large galvanized can in a room of very low humidity whose temperature ranged from 70 to 80 degrees F. The first picking of Beltsville seed was stored on September 13 and the second on September 27. The Greeley, Colorado, seed was



received and stored on October 20, and the Charleston, South Carolina, seed about October 23.

For the germination test, the first picking of the Beltsville seed that matured under humid conditions was handled as one series while the seed of the second picking that matured under dry weather conditions was handled as another series. The seed in each series was further divided into weather-spotted and clean seed, separated into the size classes shown in Table I, and weighed just before planting. Eight replications of 25 seed of each lot, when available, were planted on February 17, 1938, 1 inch deep with the hilum down in sterilized sand in flats 3 x 14 x 24 inches in size. The 14-inch rows were 2 inches apart and starting at one end of the flat there were adjacent rows of clean and spotted seed of each size with an increase in seed size be-

TABLE I—AVERAGE WEIGHT ON FEBRUARY 15 OF LIMA BEAN SEEDS OF EACH CLASS IN MILLIGRAMS

Production Locality	Weather Conditions During Ripening Period of Seed	Surface Appearance of Seed	Seed Size (Diameter in Inches)*					
			18/64	20/64	22/64	24/64	26/64	28/64
Beltsville, Maryland . . .	Humid†	Clean	150	245	290	345	469	425
Beltsville, Maryland . . .	Humid	Spotted	108	190	250	320	374	439
Beltsville, Maryland . . .	Dry‡	Clean	135	270	315	380	395	454
Beltsville, Maryland . . .	Dry	Spotted	90	200	275	325	365	420
Greeley, Colorado . . .	Dry	Clean	140	205	250	335	390	455
Charleston, South Carolina	Humid	Clean	160	250	320	375	435	—

\*Seed which passed over the smaller sized screen but through each of the mentioned sized screen. For example 20/64th inch size refers to seed that passed over screen 18/64th inch but through screen 20/64th inch.

†Atmospheric air contained an excessive amount of moisture.

‡Atmospheric air contained very little moisture.

tween each pair of rows from one end of the flat to the other. Each of eight flats therefor contained 25 seeds of each of the six different sizes of clean and spotted seeds when sufficient seed was available. In the 18/64th-inch diameter size, only 50 clean seed and 125 spotted seed of the first harvest were available for testing. In the 26/64th-inch size, 175 clean and 179 spotted seed were available for testing. In the 28/64th-inch size, 82 spotted seed were available for testing. Of the second harvest seed, there were only 86 clean seeds and 100 spotted seeds in the 28/64th-inch size.

Weather-spotted seeds were those on which there were light brown slightly sunken areas. Seeds obviously containing lesions caused by disease organisms were discarded. The clean seeds had unspotted, clean, unbroken seed coats and plump cotyledons.

The sterilized sand in which the seed was planted was kept moistened with water drawn from a hot water line that was placed in an open barrel in the greenhouse for 24 hours before it was used for watering purposes. The greenhouse temperature was maintained between 70 and 80 degrees F with an average of 75 degrees F.

The Beltsville grown seed was planted on February 17, 1938, and germination counts were made on February 25. The seed was counted as germinated, if the cotyledons were lifted above the soil level. A record was also made of the number of seedlings classified as baldheads,

snakeheads, single cotyledons, adherent seed coat, short hypocotyls or diseased. Diseased plants were those with one or more brown lesions on the hypocotyl, epicotyl or primary leaves. Baldheads, snakeheads, single cotyledons and short hypocotyls were the types described by Bainer and Borthwick (2), and were harvested on February 28 when the tops of all normal seedlings were cut at the ground line and weighed immediately in bulk to the nearest one-tenth gram in order to obtain an index of the relative vigor of the seedlings.

The above-described method was also used for testing the germination and vigor of seedlings from seed that matured at Greeley, Colorado; and Charleston, South Carolina. Two hundred seeds of each size were available for the test except in the Charleston material where there were no seeds in the largest size (28/64-inch diameter) and only 100 seeds in the smallest size (18/64-inch diameter). This seed was planted on March 4, germination counts were made on March 11, and the seedling weights secured on March 16, 1938.

### RESULTS

The number of seedlings classified as snakeheads, baldheads, one cotyledon and short hypocotyl in the Beltsville seed was so small and so evenly distributed among the different classes that the detailed data are not given. In the clean seed of all sizes and from the two harvests there were less than 2 per cent of all these classes, while in the spotted seed the percentage was 3.7. Practically all cases of baldheads were the result of pathogenic infection and many of the short hypocotyls were found to result from death of the primary root caused by disease organisms. Damage due to threshing was therefor negligible.

The percentage of adherent testas was 3.8 in the clean seed and 12.6 in the spotted seed grown at Beltsville. This adhesion of the seed coat to the cotyledon occurred at one or several of the spots caused by weathering in the spotted seeds. Eighty-five per cent of the adherent testas in the clean seed class occurred on individuals grown from seed matured under humid conditions, indicating that even on apparently sound seed there are defective areas in the seed coats.

There was 2.3 per cent of abnormal seedlings and 8.2 per cent of normal seedlings with adherent seed coats in the Charleston material, while in the Greeley material the respective percentages were .27 and 1.4. None of the ungerminated seed had hard seed coats.

The data in Table II show that a higher percentage of diseased seedlings developed from weather-spotted Beltsville seed that matured

TABLE II—PERCENTAGE OF DISEASED SEEDLINGS OF LIMA BEAN SEED OF EACH CLASS BASED ON NUMBER OF GERMINATED SEEDLINGS

Production Locality	Weather Conditions During Maturity	Surface of Seed	Diameter of Seed (Inches)					
			18/64	20/64	22/64	24/64	26/64	28/64
Beltsville, Maryland	Humid	Clean	0.0	9.3	5.9	7.8	3.8	1.7
Beltsville, Maryland	Humid	Spotted	7.9	23.4	26.0	15.6	16.0	10.0
Beltsville, Maryland	Dry	Clean	1.0	1.0	1.0	—	0.0	0.0
Beltsville, Maryland	Dry	Spotted	2.4	5.9	6.5	—	10.3	6.8
Charleston, South Carolina	Humid	Clean	1.3	1.3	2.5	4.7	1.8	—
Greeley, Colorado	Dry	Clean	0.0	0.0	0.0	1.5	0.0	1.0

under humid weather conditions than from weather-spotted seed that matured under dry weather conditions. Even with clean seed, more diseased seedlings were produced from seed that matured under humid than under dry weather conditions. Clean seed produced more healthy seedlings than weather spotted seed. The Greeley, Colorado, seed had very few diseased seedlings, which was similar to the results obtained from the Beltsville clean seed that matured under dry weather field conditions. The Colorado seed also produced more healthy seedlings than seed grown at Charleston, South Carolina.

TABLE III—PER CENT OF GERMINATION OF CLEAN AND WEATHER-SPOTTED LIMA BEAN SEED OF DIFFERENT SIZES FROM SEED MATURED DURING HUMID OR DRY WEATHER CONDITIONS AT BELTSVILLE, MARYLAND, IN 1937

Seed Size, Diameter (Inches)	Weather During Maturity	Germination			
		Clean Seed		Spotted Seed	
		Range (Per Cent)	Average (Per Cent)	Range (Per Cent)	Average (Per Cent)
18/64	Humid	68-88	78.0a	40-68	50.4b
18/64	Dry	88-100	95.5	52-88	63.5c
20/64	Humid	64-100	75.5	12-52	32.0
20/64	Dry	96-100	99.5	76-96	84.5
22/64	Humid	60-96	84.0	28-48	36.5
22/64	Dry	96-100	99.0	64-88	76.5
24/64	Humid	60-96	83.5	40-64	45.0
24/64	Dry	92-100	98.5	40-88	65.5
26/64	Humid	80-96	89.2	20-40	27.5
26/64	Dry	92-100	99.0	32-100	48.5
28/64	Humid	12-84	40.0d	32-100	42.7e
28/64	Dry	80-100	89.6	28-60	44.0f

A difference of 9.9 per cent between any two averages is significant with odds of 19 to 1.

#### Analysis of Variance

Source of Variation	Degrees of Freedom	Mean Square
Total	127	44.13
Between replications	7	7.46h
Between sizes	3	23.81g
Between clean and spotted seed	1	3041.99g
Between weather conditions	1	1200.50g
Sizes X spotted vs. clean seed	3	67.44g
Sizes X weather	3	57.14g
Clean vs. spotted seed X weather	1	150.24g
Seed size X clean vs. spotted seed X weather	3	191.90g
Remainder (error)	105	4.98

aAverage 2 replications

bAverage 5 replications

cAverage 8 replications

dAverage 8 replications

eAverage 4 replications

fAverage 4 replications

gExceed the 1 per cent point.

hNot significant.

Not used in analysis of variance

The seed which matured at Beltsville under humid weather conditions had a significantly lower germination percentage than seed from the same plants matured under dry weather conditions regardless of the size of seed or whether the seed was clean or spotted (Table III). Clean seed produced a significantly greater percentage of seedlings than spotted seeds and the differences obtained were greater than

between seed that matured during humid versus dry weather. There were no significant differences in germination of clean seed of the majority of the different sizes, but in the spotted seed the larger sizes produced fewer plants than the smaller, and this was especially the case with those that matured during dry weather.

TABLE IV—AVERAGE GREEN WEIGHT OF ABOVE GROUND PORTION OF LIMA BEAN SEEDLINGS FROM CLEAN AND WEATHER SPOTTED SEED OF DIFFERENT SIZES THAT MATURED DURING HUMID OR DRY WEATHER CONDITIONS AT BELTSVILLE, MARYLAND, IN 1937

Seed Size, Diameter (Inches)	Weather During Maturity	Green Weight of Seedlings			
		Seed Condition			
		Clean		Spotted	
		Range (Mg)	Average (Mg)	Range (Mg)	Average (Mg)
18/64	Humid	483 to 672	567 <sup>a</sup>	325 to 417	368 <sup>b</sup>
18/64	Dry	525 to 778	695	300 to 480	374 <sup>c</sup>
20/64	Humid	727 to 1196	942	450 to 1023	683
20/64	Dry	956 to 1284	1175	700 to 1030	867
22/64	Humid	1064 to 1280	1200	760 to 1185	968
22/64	Dry	1210 to 1510	1386	1025 to 1314	1175
24/64	Humid	1275 to 1655	1482	1111 to 1800	1312
24/64	Dry	1640 to 1760	1686	667 to 1466	12.03
26/64	Humid	1594 to 1909	1711	1380 to 1625	1490
26/64	Dry	1600 to 1845	1757	1200 to 1583	1389
28/64	Humid	1692 to 1890	1788 <sup>d</sup>	500 to 1780	1415 <sup>e</sup>
28/64	Dry	1728 to 1935	1807	1166 to 2030	1537 <sup>f</sup>

A difference of 228 mg between any two means is significant with odds of 19 to 1.

#### Analysis of Variance

Source of Variation	Degrees of Freedom	Mean Square
Total	127	108,747
Between replications	7	25,954 <sup>h</sup>
Between sizes	3	2,725,043 <sup>g</sup>
Between clean and spotted seed	1	2,531,249 <sup>g</sup>
Between weather conditions	1	365,268 <sup>g</sup>
Sizes X clean versus spotted seed	3	18,156 <sup>h</sup>
Sizes X weather	3	106,949 <sup>g</sup>
Clean versus spotted seed X weather	1	119,074 <sup>g</sup>
Remainder (error)	105	18,521

aAverage 2 replicates

bAverage 5 replicates

cAverage 8 replicates

dAverage 8 replicates

eAverage 4 replicates

fAverage 4 replicates

gExceeded the 1 per cent point.

hNot significant.

Not used in analysis of variance.

The data in Table IV however show that the most significant differences in green weight of seedlings were from seed of different sizes. See also Fig. 1. The larger diameter seed, whether clean or spotted, produced heavier or more vigorous seedlings than the smaller sized seeds. Clean seed always produced seedlings that were significantly heavier than weather-spotted seeds.

There was no significant difference in vigor of seedlings due to the interaction of seed sizes x clean vs. spotted seed.

A significant difference in seedling vigor of seedlings was obtained in the interaction of seed of different sizes x weather conditions under



FIG. 1. Showing effect of size of seed and weather conditions at time of seed ripening on germination and vigor of seedlings. Above.—9 day old seedlings. Above left—Seed matured under dry weather conditions at Beltsville, Maryland. Above right—Seed matured under humid conditions at Beltsville. Seedlings from each pair of rows (above) from top to bottom developed from seed of the following sizes: 18/64, 20/64, 22/64, 24/64, 26/64, and 28/64 inch diameter. The seedlings in top row of each pair of sizes developed from clean and the next row developed from weather spotted seed. Below—11 day old seedlings; (a) Charleston, South Carolina and (b), Greeley, Colorado seed. Note how the size of seedlings increases with diameter (inches) of seed from left to right.

which the seed ripened. Dry weather conditions during the period of seed ripening increased the vigor of seedlings of each size group.

The interaction of clean vs. spotted seed x weather conditions during ripening period of seed also produced significant differences in vigor of seedlings. Again dry conditions during maturity was responsible for increased vigor of seedlings from either clean or weather spotted seed.

Seed grown at Greeley, Colorado, produced a significantly greater percentage of seedlings than that grown near Charleston, South Carolina, as is shown in Table V. In the Greeley grown seed there

TABLE V—PER CENT OF GERMINATION OF LIMA BEAN SEED OF DIFFERENT SIZES GROWN AT GREELEY, COLORADO, AND CHARLESTON, SOUTH CAROLINA, IN 1937

Seed Size, Diameter (Inches)	Germination of Seed Produced at			
	Charleston, South Carolina		Greeley, Colorado	
	Range (Per Cent)	Average (Per Cent)	Range (Per Cent)	Average (Per Cent)
18/64	72 to 88	78.0	72 to 96	82.0b
20/64	64 to 88	76.0	80 to 100	92.0
22/64	72 to 96	82.0	84 to 100	95.0
24/64	60 to 92	75.0	92 to 100	97.0
26/64	44 to 64	50.3	92 to 100	99.0
28/64			92 to 100	99.5c

A difference of 7.0 per cent between any two averages is significant with odds of 19 to 1.

#### Analysis of Variance

Source of Variation	Degrees of Freedom	Mean Square
Total	63	15,969
Between localities	1	188,417d
Between sizes	3	24,640d
Between replications	7	2,927e
Locality X sizes	3	172,800d
Remainder (error)	49	3,089

aAverage 4 replications

bAverage 8 replications

cAverage 8 replications

dExceeds the 1 per cent point.

eNot significant.

was no significant difference in germination percentage between seed sizes but in the Charleston grown seed the largest size seed produced the lowest percentage of seedlings. The total variance due to size was therefore mainly contributed by the seed from Charleston.

In average green weight of seedlings there was no significant difference between Greeley and Charleston grown seed when all sizes of seed are considered as is shown in Table VI. The larger seeds from both localities produced significantly heavier seedlings than smaller seeds.

The significant difference due to replication is probably the result of the time interval involved in securing the green weights. Harvesting started at 9 a.m. and was continued until 4 p.m. The morning harvested replications may have been heavier than the afternoon harvested replications due to loss of water by transpiration.

TABLE VI—AVERAGE GREEN WEIGHT OF ABOVE GROUND PORTION OF LIMA BEAN SEEDLINGS FROM SEED OF DIFFERENT SIZES PRODUCED NEAR GREELEY, COLORADO, AND CHARLESTON, SOUTH CAROLINA, IN 1937

Seed Size, Diameter (Inches)	Seed Source			
	Charleston, South Carolina		Greeley, Colorado	
	Seedling Weight		Seedling Weight	
	Range (Mg)	Average (Mg)	Range (Mg)	Average (Mg)
18/64	526 to 695	597	410 to 575	501 <sup>b</sup>
20/64	850 to 1033	928	760 to 952	858
22/64	1000 to 1258	1155	1023 to 1133	1086
24/64	1200 to 1529	1403	1087 to 1600	1399
26/64	1369 to 1888	1602	1520 to 1900	1733
28/64			1860 to 2300	2012 <sup>c</sup>

A difference of 158 mg between any two means is significant with odds of 19 to 1.

## Analysis of Variance

Source of Variation	Degrees of Freedom	Mean Square
Total	63	968.76
Between replications	7	218.71 <sup>e</sup>
Between seed sizes	3	18,014.33 <sup>d</sup>
Between localities	1	5.50 <sup>f</sup>
Locality X sizes	3	384.33 <sup>d</sup>
Remainder (error)	49	87.74

aAverage 4 replicates

bAverage 8 replicates

cAverage 8 replicates

dExceeds the 1 per cent point.

eExceeds the 5 per cent point.

fNot significant.

Not used in analysis of variance.

## DISCUSSION

The adherence of the seed coats to the cotyledons frequently prevents the spreading of the cotyledons and the issuance of the plumule. The enclosure of the plumule between the cotyledons exposes it to attack by disease organisms under conditions favorable for their rapid growth. The majority of baldheads in these experiments were the result of infections of this sort.

Seedsmen have long since learned that to secure high germination percentage and to prevent the spread of seed-borne diseases it is necessary to cull out all spotted seeds. The spotted seed was included in this experiment to determine its value because the amount of seed of this new variety was very limited. The great reduction in germination would not justify the use of weather-spotted seed commercially but in view of the percentage of seedlings produced its use for increase purposes would seem to be justified if grown in an isolated plot to prevent the spread of diseases that may be carried on the seed.

Few of the seedlings recorded as diseased succumbed, nor did the lesions increase in size, during the period between their emergence and harvest, and it is not known how many of the brown lesions were due to slight injury during the threshing process as pointed out by Harter (3) or to pathogenic infection. An inspection of many of the rotted seeds by L. L. Harter revealed only saprophytic organisms and no *Macrophomina phaseoli* found by Andrus (1) to be a factor in reduced

germination and seedling infection of lima bean seed grown under humid weather conditions near Tifton, Georgia. These observations would seem to indicate that pathogenic organisms played a minor role in the production of lesions on the seed or in the failure of the seeds to germinate.

The evidence from the Beltsville grown material would seem to indicate that conditions during maturity are very important in the production of lima bean seed of high germination. The two Beltsville lots were from the same plants, the interval between harvests was only 2 weeks, both lots were dried and stored under the same conditions and yet the lot which matured under humid conditions had the lowest germination percentage. Simpson (5) reports that cottonseed that matured during a period of excessive moisture had a higher moisture content and a lower germination percentage than seed that matured during dry weather. The Charleston and Greeley data also suggest better germination from seed matured under dry conditions, but in this comparison the difference in temperatures, soils and drying conditions enter as complicating factors.

The moisture content of the seed was not determined before or after storage, so it is impossible to estimate the loss of viability during storage or to correlate the moisture content with germination.

Many other workers with other crops have shown a direct relation between the size of seed and seedling but no reports on lima beans were found. Rudolf (4) working with *Phaseolus vulgaris* obtained results similar to those reported herein.

#### SUMMARY

Clean lima bean seed of the Baby Fordhook variety that matured during a humid period at Beltsville, Maryland, had a much lower germination percentage than seed from the same plants that matured during dry weather. Seed from the same stock matured under humid conditions at Charleston, South Carolina, also had a lower germination percentage than seed which matured under dry conditions at Greeley, Colorado. Seed with weather spots on the seed coat produced a lower germination percentage than clean or unspotted seed that matured under the same conditions.

More diseased seedlings occurred from weather spotted than from clean seed. Size of seed had no effect on germination percentage when the seed matured under dry weather conditions and was free from weather spots. The size of seedling as measured by the green weight of the above ground portion 11 or 12 days from date of planting, was directly proportional to the size (diameter and weight) of the seed.

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## A Quantitative Study of Form and Size in Five Varieties of Carrots<sup>1</sup>

By W. H. LACHMAN,<sup>2</sup> *Massachusetts State College, Amherst, Mass.*

THE plant breeder and the vegetable specialist deal with numerous characteristics of plants which are not clearly defined, such as shape of marketable portion of the plant, uniformity and relative smoothness all of which are commercially important but difficult to measure or express quantitatively. Differences in size, furthermore, are frequently not clearly distinguished, and classification based on size is not readily possible. These characters, which constitute what is known as "type" in commercial strains and varieties of vegetables, have generally been compared qualitatively and only a few quantitative studies have been attempted. It is essential that studies be made, however, in order that satisfactory comparisons of varieties be possible, and in order to ascertain whether progress is being achieved in type improvement.

In this study, the attempt has been made to measure shape in several varieties of carrots, to compare its variability with that of size, to ascertain whether it differed significantly among the varieties and to determine to what extent it might be influenced by soil variability.

Five varieties of carrots were planted in 25 plots arranged in a Latin square as described by Love (2). The plots consisted of a single row 27 feet long with 3 feet between rows. The varieties were located so that each variety occurred once in each column and once in each row.

The soil was well prepared, and was treated uniformly with 4-16-4 fertilizer at the rate of 760 pounds to the acre, applied with a grain drill several days before planting the seed. The seed was planted by hand in drills about  $\frac{1}{2}$  inch deep on May 23, 1935.

Because of extremely dry weather it was necessary to irrigate before the seed germinated. Frequent shallow cultivation was given to control weed growth. The plants were thinned to a uniform stand of six per foot of row, when they were about 2 inches tall, and no conscious choice was made in favor of leaving the strongest growing carrots.

Measurements were begun on September 26 and were completed about 2 weeks later. Data were taken by cutting each carrot longitudinally and measuring the polar diameter and the equatorial together with its two quartile transverse diameters in centimeters. The measurements were made by means of a specially prepared scale, described by Mack and Lachman (4).

Fifty carrots were selected at random from each plot, or in other words 250 roots of each of the five varieties were measured. Three shape indices were computed for each root by dividing the upper quartile, equatorial and lower quartile diameters by the polar diameter. An index to the volume of each root was computed by substituting in

<sup>1</sup>Contribution No. 330 of the Massachusetts Agricultural Experiment Station.

<sup>2</sup>The author wishes to express his appreciation to Dr. Warren B. Mack of the Pennsylvania Agricultural Experiment Station for having suggested this study.

the formula  $V. I. = \frac{\Pi \times E. D.^2 \times P. D.}{6}$  in which E. D. is the equatorial

diameter and P. D. is the polar diameter.

Summaries of the data are presented in Tables I and II. The averages for each plot are arranged in the table in the same order as they occurred in the plots of the Latin square in the field. Fisher's Analysis of Variance was used in analyzing the data, Love (2).

TABLE I—PLOT ARRANGEMENT AND INDICES OF FORM AND SIZE OF CARROT VARIETIES

	Column 1	Column 2	Column 3	Column 4	Column 5
Row 1	<i>B</i>	<i>A</i>	<i>E</i>	<i>C</i>	<i>D</i>
Upper index	0.393	0.258	0.369	0.232	0.237
Middle index	0.349	0.209	0.311	0.237	0.206
Lower index	0.269	0.154	0.239	0.226	0.183
Volume index	44.2	38.5	43.6	38.6	68.2
Row 2	<i>D</i>	<i>B</i>	<i>C</i>	<i>A</i>	<i>E</i>
Upper index	0.213	0.424	0.239	0.285	0.386
Middle index	0.190	0.360	0.247	0.242	0.314
Lower index	0.151	0.284	0.226	0.186	0.233
Volume index	39.6	51.6	38.4	56.1	48.2
Row 3	<i>A</i>	<i>D</i>	<i>B</i>	<i>E</i>	<i>C</i>
Upper index	0.253	0.209	0.402	0.368	0.231
Middle index	0.206	0.174	0.351	0.311	0.233
Lower index	0.151	0.144	0.276	0.249	0.222
Volume index	40.4	39.7	56.0	58.7	46.0
Row 4	<i>E</i>	<i>C</i>	<i>D</i>	<i>G</i>	<i>B</i>
Upper index	0.354	0.210	0.245	0.217	0.417
Middle index	0.321	0.212	0.198	0.202	0.368
Lower index	0.253	0.198	0.155	0.165	0.298
Volume index	46.7	40.9	47.1	55.3	57.2
Row 5	<i>C</i>	<i>E</i>	<i>D</i>	<i>B</i>	<i>A</i>
Upper index	0.223	0.354	0.210	0.422	0.275
Middle index	0.225	0.310	0.187	0.382	0.232
Lower index	0.202	0.257	0.165	0.303	0.185
Volume index	37.4	43.9	51.4	61.7	55.7

*Means of Varieties*

Variety	Upper Index	Middle Index	Lower Index	Volume
A	0.2632	0.2174	0.1662	47.56
B	0.4116	0.3620	0.2860	54.14
C	0.2270	0.2308	0.2148	40.26
D	0.2172	0.1918	0.1576	50.84
E	0.3662	0.3134	0.2462	48.22

TABLE II—ANALYSIS OF VARIANCE OF INDICES OF FORM AND SIZE OF CARROT VARIETIES

Variation Due to	Degrees of Freedom	Mean Square or Variance			
		Upper Index	Middle Index	Lower Index	Volume Index
Varieties	4	0.03792	0.02566	0.01461	132.13
Columns	4	0.00045	0.00042	0.00038	191.37
Rows	4	0.00031	0.00018	0.00015	11.71
Error	12	0.00004	0.00009	0.00012	33.92
Total	24	0.00647	0.00442	0.00258	72.85

Difference required for significance

between means (odds of 30 to 1) 0.00826 0.01214 0.01386 7.34

It is readily apparent that the variance due to varieties is decidedly greater than the variance from any other source. Significant differ-

ences in shape index appear among all the comparisons possible except between varieties A and D in the lower shape index. The differences among the means of the upper, middle and lower shape indices are significant if they show greater differences than 2.77, 4.53, and 6.56 per cent, respectively.

Variety A, for example, considering the middle index has an average coefficient of variability of 26.26 per cent and according to the formula of Livermore and Neely (3) requires 256 roots to measure a 5 per cent difference.

The shape index of .242 for variety A, row 2, column 4, seems to be unreasonably high. When the value of this plot is estimated by the formula of Allan and Wishart (1) this value becomes .222. Even though the estimated shape index for this plot is considerably less than the observed value, when the data are analyzed with a loss of 1 degree of freedom, the variance due to error becomes .00010, just a little higher than the observed. The difference needed for significance is .01264 and on this basis the 10 possible comparisons among the mean middle shape indices all show significant differences.

Considering size as represented by volume index, the variance due to columns is about 17 times as great as variance due to rows. True enough, the columns cover a greater distance of ground and from general appearance the soil in the east end of the field was lighter in texture and more stony than was the west end. It is clearly seen that volume is influenced by soil variability to a much greater extent than is the shape of roots. Variance in volume of roots due to variety is less than that due to columns and a 15.28 per cent difference in volume is necessary between the means of varieties to show a significant difference, which occurs among varieties B and C, C and D, and C and E.

While there is some variability in both the shape and size of carrots, it is apparent that shape is decidedly the more constant of the two characters and is less influenced by soil variability. When studied on a statistical basis shape indices may be manipulated with confidence and small though clear-cut differences may be ascertained.

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# The Relation of Certain Floral Abnormalities to the Pollination of Cucurbita

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## ABSTRACT

**I**NCIDENTAL to an investigation of the factors influencing fruit setting and development of the cultivated cucurbits, certain anatomical irregularities were observed in the nectaries and surrounding tissues in the Cucurbita which appeared to influence insect visitation and subsequently the pollination of the flowers.

In the staminate flowers the irregularities were in the absence of and the size of the apertures found in the flask-like structure formed over the nectary by the fusion or partial fusion of the anthers. The exclusion of insects from the nectary may result from (a) the complete fusion of all the filaments; (b) the partial cohesion of the anthers with a membrane formed over the aperture; or (c) a combination of these two conditions. Wide variation in the size of the apertures were found within and between the various varieties studied.

In the pistillate flowers closed nectaries resulting from filamentous staminodia were found to be peculiar to the varieties of *Cucurbita pepo* with disk-shaped fruits. The major abnormalities in the pistillate flowers of Cucurbita were in the location of the nectary in relation to the lobes of the stigma and the spread of the corolla.

As fruit shape, size and color are the results of the expression of inheritable characters in the ovary primordium, it seems feasible to expect that the floral abnormalities reported in this paper may be eliminated by the selection and inbreeding of pure lines which are free of flowers with closed nectaries and elongated styles.

# The Influence of Climatological Factors on Anthesis and Anther Dehiscence in the Cultivated Cucurbits. A Preliminary Report<sup>1</sup>

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THE technique of artificial pollination of cucurbit flowers has been discussed in numerous articles in the horticultural literature. Most of these accounts deal with covering or tying the flowers the day before anthesis to prevent contamination from foreign pollen. However, in many cases where the best known techniques have been followed, poor sets of fruit have resulted. A large number of artificial pollinations have been made at the Michigan Station over several years in connection with breeding projects on cucumbers and cantaloupes and only from 5 to 10 per cent developed fruit. In a study of the results, considerable variation was revealed between the different days. A high percentage of the pollinations made on certain days were successful, while under slightly altered conditions practically none were effective. Furthermore, during the 1936, 1937, and 1938 seasons wide fluctuations in the number of flowers setting fruit on different days have been noted with naturally pollinated cucumbers. Most of the authorities recommend early morning pollinations and under certain climatic conditions they are the most effective. The writers have obtained much better sets from afternoon pollinations on certain days. Hourly microscopic examinations of staminate flowers of various cucurbits have shown that under favorable conditions the anthers may dehisce any time during the day, while on cool days they may not dehisce at all. As it is not likely to effect pollination if flowers with closed anthers are used, any pollination attempts made before dehiscence are futile. An investigation of the factors influencing fruit setting and development of the cucurbits is under way at the Michigan Station and the influence of certain climatological factors on anthesis and anther dehiscence will be discussed in this paper.

## MATERIALS AND METHODS

The investigations before 1938 were confined to the pickling type of cucumbers with occasional observations on cantaloupes. Some rather distinct differences in bee activity were noted in adjoining plots of cucumbers and cantaloupes in 1937, and in 1938 the following varieties of the major species of cucurbits were included in the studies: *Cucumis sativus*—National Pickling and Long Green; *Cucumis melo*—Honey Rock, Hearts of Gold, Hales Best, Honey Dew, and Golden Casaba; *Cucumis anguria*—West India Gherkin; *Citrullus vulgaris*—Harris Early and Stone Mountain; *Cucurbit pepo*—White Bush Scallop and Connecticut Field; *Cucurbita moschata*—Green Striped Cushaw; and *Cucurbita maxima*—Blue Hubbard.

<sup>1</sup>Journal Article No. 342 (n. s.) from the Michigan Agricultural Experiment Station.

At least 50 hills of each of the varieties were planted and later thinned to three plants per hill. The plants were well fertilized and the young undeveloped fruits were removed as soon as they were detectable. The removal of the fruits before they attained any appreciable size kept the vines growing vigorously and an abundance of both pistillate and staminate flowers were available from early August until frost in October.

Field observations of the anthers and nectaries of at least 10 flowers of each of the varieties were made hourly with a binocular microscope using 10X eye pieces and a set of 20X paired objectives. Temperatures and humidities were recorded by a hygrothermograph located in the field and which was checked several times daily with a psychrometer. Hourly evaluations were made on the conditions of sunlight, wind movements, stage of anthesis, and bee activity both at the hive and in the field. The readings were expressed on a numerical basis ranging from 0 to 9. The daily records for each variety were kept separately. Only those phases of the investigation concerned with anthesis and anther dehiscence will be considered here.

#### PRESENTATION OF RESULTS

*Observations Made in 1937:*—In the 1937 investigations with cucumbers the time of day and temperature influenced the time of anthesis and anther dehiscence more than any of the other climatological factors studied. Under the normal climatic conditions at East Lansing during August and September anthesis and dehiscence usually occur between 6 a.m. and 9 a.m. The mean of 140 observations in 1937 was 8 a.m. However, on warm days fully opened flowers with dehiscent anthers were observed as early as 4 a.m., while on cool days (55 degrees F or below) the flowers and the thecae of the anthers remained closed throughout the day. The time of day and the stage of anther dehiscence were correlated on the 140 observations made in 1937 and a highly significant (1) coefficient of correlation ( $r$ ) of  $.2724 \pm .0528$  was obtained.

Though the time of day was apparently a controlling factor of anthesis and anther dehiscence it undoubtedly was modified by temperature. At temperatures below 60 degrees F the flowers remained closed and the pollen sacs did not rupture but the corollas were always expanded fully and the anthers dehiscent at 70 degrees F. When 126 observations of temperature and the stage of anther dehiscence were correlated, a highly significant value for  $r(1)$  of  $.6017 \pm .0383$  was secured. The mean of all the observations was approximately 65 degrees F.

Under the conditions prevailing at East Lansing in 1937 humidity apparently was not operative in influencing the time of anthesis or dehiscence. Fully expanded flowers with dehiscing anthers were observed at relative humidities as low as 25 or 30 per cent and were also observed under saturated conditions during showers. A large number of observations between humidity and dehiscence were plotted on a correlation table, but the values were scattered widely and no correlation was apparent. Cloudiness and freedom from clouds in the atmosphere undoubtedly influenced temperatures, but in these studies

showed little relation to anthesis and dehiscence. Observations made when the skies were overcast showed the anthers to be completely closed in 12 instances and fully expanded in 11 cases. Likewise, when clear skies prevailed, the anthers were closed in 23 cases and dehiscing fully in 27 cases. Bee activity in the cucumber flowers was found to be closely related to the stage of the blossoms. Under most conditions when pollen and nectar were present in sufficient quantities the honey, bumble, and solitary bees were actively engaged in collecting these materials.

*Observations Made in 1938:*—In all of the species and horticultural varieties included in the 1938 studies, the primary climatological factors which influenced anthesis and anther dehiscence were the same as those operative in the cucumbers in 1937, namely, temperature and time of day. The latter in each case was influenced directly by the former. Based on the optimum temperatures for anthesis and dehiscence the species may be separated in three groups as follows: (a) the pumpkins and squashes; (b) the watermelons, gherkins, and cucumbers; and (c) the cantaloupes, honey dews, and casabas.

In all of the species and varieties of *Cucurbita* studied, the minimum temperature for anthesis and the dehiscence of the pollen sacs was between 48 and 50 degrees F with the optimum being between 50 and 55 degrees F. The White Bush Scallop variety opened slightly later than the others. Sunlight apparently exerted little influence on the opening of the flowers of this genus. They were always open at day-break if the temperature was above 50 degrees F. As early as 9 p.m. on warm nights the corollas of some of the flowers started to unfold and the thecae at the tips of the anthers began to rupture. Under optimum temperature conditions (50 to 55 degrees F) the corollas were extended fully, and all of the thecae of the anthers dehisced at 2 a.m. The length of time the flowers remained open depended on the temperature and humidity. When the temperature was low (50 to 55 degrees F) and the humidity high (75 per cent or over) they would remain open until noon or later. However, under the higher temperatures and lower humidities which normally prevailed the corollas would start to wither as early as 8 a.m. The turgid condition of the corollas in the flowers of this genus was much more sensitive to high temperatures and low humidities than it was in the other genera studied.

Anthesis occurred in the watermelon, gherkin, and cucumber at temperatures between 58 and 60 degrees F. Dehiscence started from 62 to 63 degrees F and reached its optimum between 65 and 70 degrees F. In this class the watermelon flowers were the first to open and dehisce, followed by the gherkin and then the cucumber. If the day before anthesis was cool (below 60 degrees F) the maturity of the watermelon blossoms was delayed and higher temperatures than those given were required for both anthesis and dehiscence. Anthesis did not occur as readily on cool mornings in the gherkin flowers as in the flowers of *Cucurbita* and *Citrullus*, but under cool temperatures the anthers would dehisce before the corollas were more than one-half unfolded. No differences were observed between the pickling and slicing

types of cucumbers. They both responded to temperature and other factors as reported in the 1937 observations.

A slight variation in temperature response was noted between the two sub species of *Cucumis melo*. In the cantaloupes (*C. melo* var. *reticulatus*), represented by the Honey Rock, Hearts of Gold, and Hales Best varieties, anthesis and dehiscence took place earlier than in the winter melons (*C. melo* var. *inodorus*), represented by the Honey Dew and Casaba varieties. The temperature relationships between the other two classes and the sub species of this class are well illustrated by the conditions observed at 9 a.m. on August 24 and 25 when the temperature was 65 degrees F. The squash and pumpkin flowers had been open for several hours and the corollas had begun to wither; the watermelon, gherkin, and cucumber flowers were expanded fully; the cantaloupe flowers were one-half unfolded; and the Honey Dew and Casaba flowers were only one-quarter open.

The minimum temperature for anthesis and dehiscence in the cantaloupe was 65 degrees F while the optimum was between 68 and 70 degrees F. In the Honey Dew and Casaba anthesis does not take place below 68 degrees F, but dehiscence may occur at 65 degrees F, with the optimum for both anthesis and dehiscence being 70 to 75 degrees F. Maturity of the cantaloupe and Honey Dew flowers may be delayed by low temperatures the day before anthesis. If cool temperatures prevail the next morning the opening of the flowers is retarded and slightly higher temperatures than the minimums given are required for complete anthesis. However, as was the case in the watermelon dehiscence occurs at the temperatures given.

Climatological factors, other than temperature, apparently were not operative in any of the three classes. Flowers opened and released their pollen when the humidity was low and equally as well during rainy weather. Wind movements frequently caused sudden changes in temperature, but if the temperature was within the optimum range for the species no effect was noticeable. In all the observations the flowers borne above the leaves and exposed to the sun would open earlier than those in the shade under the leaves. But here again the determining factor was temperature as they all opened at the same time when cloudy weather prevailed. The activity of the bees in the flowers early in the morning was found to be a good indicator of the stage of anther dehiscence with but few exceptions.

### DISCUSSION

The data presented indicate that temperature is the most important of all the climatological factors influencing the dehiscence of the pollen-sacs of the Cucurbitaceae. Slight gradients in temperature response makes it possible to group the cultivated species into three classes. The studies further show that dehiscence may occur at any hour of the day and under unfavorable temperatures the flowers may remain closed throughout the day. The critical temperatures for the dehiscence of the various species have been determined. Indications are that plant breeders working with these plants should give them special consideration before pollinations are attempted. Where bags are used to cover the



flowers, the temperatures within the bags may be different from those outside of the bags. Observations on bagged flowers showed the same temperature relations as unbagged flowers. It is suggested that the person making the pollinations watch the thermometer closely or examine the anthers of several flowers with a strong lens before starting to work. Even if the anthers are fully dehiscent and large quantities of pollen are applied to the stigmatic surfaces, failure may be experienced. The viability of the pollen, the receptivity of the stigmas, the germination and growth of the pollen tubes, and the fertilization of the ovules may all be affected by the entrance of other factors.

It may be argued that too definite temperature conditions for dehiscence have been set up for the various species. Unpublished studies on tree fruit pollination by the junior author have shown marked effects of a slight temperature gradient at different levels in the same tree. Under still conditions when wind movements did not affect temperatures, a gradient of approximately 1 degree F for every 10 feet of elevation above ground level was established. Under such conditions the flowers in the top of the tree would be dehiscing and show considerable insect activity while those on the lower branches would not be dehiscing and consequently were not being pollinated. Some seasons when cold, unfavorable conditions prevail during the blossoming period good sets of fruit may occur only in the tops of the trees.

The conditions at which anther dehiscence occurs in the cultivated cucurbits is of minor importance on days with rapidly rising temperatures. However, the minimum temperature for dehiscence is of major importance to the successful pollination of these plants on those days when the temperatures are near the critical points established by these studies.

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## Induced Parthenocarpy of Watermelon, Cucumber and Pepper by the Use of Growth Promoting Substances<sup>1</sup>

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**P**ARTHENOCARPY is the production of fruit without fertilization. When seedless fruit develops without fertilization, the condition is called vegetative, autonomic or "natural" parthenocarpy. If the formation of a fruit depends upon, or is influenced by, the stimulus of pollen on the stigmas or by the growth of pollen tubes in the style or ovary or by hormones and other physical-chemical stimulus on or in the style or ovary, the condition is called stimulative, aitinomic or "artificial" parthenocarpy (9).

Natural parthenocarpy commonly occurs in banana, citrus fruits, vinifera grapes, Chinese persimmon, tomatoes and English greenhouse cucumbers; it is rare in watermelon and American cucumber and has not been reported in peppers. Due to the fact that seedless fruit is usually preferred in the market, efforts have been made (a) to obtain seedless fruits by breeding, (b) to induce parthenocarpic from non-parthenocarpic fruits, and (c) to increase the percentage of parthenocarpic fruits where some occur normally. With the last two objectives in mind, an experiment was conducted by the writer during the summer of 1938 with watermelon, cucumber, and pepper.

The first attempts to induce fruit setting with known chemicals was carried out by Hartley in 1902 (6). He treated the stigmas of a seedy variety of sweet orange with magnesium sulphate but failed to induce fruit setting. By treating the ovaries with known hormones in lanolin paste, parthenocarpic fruits have been secured by Gustafson (2, 3, 4, 5) in tomatoes, peppers, crook-neck squash, eggplants, and some ornamental plants. He failed to secure such fruits in watermelon, summer and winter squash and pumpkins. His results with cucumbers were also not very satisfactory. Gardner and Marth (1) obtained parthenocarpic fruits of American holly by spraying the pistillate flowers with naphthalene acetic acid and indole-butylic, indole-acetic and indole-propionic acids of different concentrations. A positive result was obtained in strawberries from the use of indole-acetic acid. A self-sterile variety of apple and grape gave negative results. Wong (11) found that indole-acetic acid and indole-butylic acid of 0.5 and 1.0 per cent in lanolin paste applied to the ovary did not induce parthenocarpic fruit in the Hamlin orange (a commercial seedless variety) even though natural parthenocarpy does exist in this variety in Florida. Varrelman (10) sprayed a normally parthenocarpic type of Navel apple with different concentrations of indole-acetic and naphthalene acids but also failed to get fruit.

Seedlessness and seediness are closely related to fruit shape and eating quality. Chinese persimmon and English forcing cucumber are

<sup>1</sup>Journal Article No. 349 (n. s.) from the Michigan Agricultural Experiment Station.

TABLE I—FRUIT SETTING IN THE NATIONAL PICKLING CUCUMBER AS A RESULT OF HORMONE TREATMENTS

Treatment	Number in Sample	Number Set	Set (Per Cent)
2.5 per cent N.A.A. lanolin paste applied to cut style cap. . . . .	30	13	43
1.0 per cent N.A.A. lanolin paste applied to cut style cap. . . . .	32	24	75
5.0 per cent N.A.A. lanolin paste applied to cut style cap. . . . .	25	5	25
No treatment except nipped-off stigma. . . . .	30	3	10
No treatment nor pollination. . . . .	44	5	11
1 per cent N.A.A. paste applied to stigma. . . . .	11	6	54
Self-pollinated. . . . .	15	8	53
Female flower sprayed with 0.05 per cent N.A.A. solution with a hand atomizer*. . . . .	42	14	33

\*This treatment was used near the end of the season which may account for the low percentage of set.

examples. In the cucumber (excluding the English forcing type) the constriction of the stem-end or blossom-end is due to seedlessness of that particular portion. According to Seaton and Kremer (7, 8) the number of parthenocarpic fruits in the National Pickling cucumber is practically nil. An experiment was conducted by the writer with this variety in an attempt to secure seedless fruits of the normal straight shape by means of growth promoting substances.

There were eight series of treatments. All of the treated blossoms were covered with wire cages before anthesis as well as 4 to 6 days after treatment. Naphthalene acetic acid (N. A. A. in short) was the only chemical used on the cucumber. The results obtained are given in Table I.

Although the number of samples was not large enough to permit any conclusive statement, they indicate that naphthalene acetic acid did cause cucumbers to set parthenocarpically, either applied in lanolin paste of 1 per cent to 5 per cent concentration or as a 0.05 per cent aqueous solution to the cut surface of the style cap or directly to the stigma (Fig. 1). Attention is called to the second treatment in Table I in which the hormone-treated flowers gave higher percentage of set than was obtained by selfing. Spraying, because it requires little time and skill, might have some commercial value in greenhouse cucumber culture.

With watermelon, 11 varieties with 12 series of treatments were used. The results obtained from the various methods of application are given in Table II.

In this experiment, no parthenocarpic fruits were formed except from those treated with N. A. A. (Fig. 2). Fruits were



FIG. 1. The National Pickling Cucumber: A longitudinal section of typical naphthalene acetic acid-treated cucumbers, showing the "undeveloped seeds", compared with open-pollinated cucumbers.

TABLE II—FRUIT SETTING IN THE WATERMELON AS A RESULT OF HORMONE TREATMENTS

Treatment	Number of Blossoms	Number Set	Set (Per Cent)	Remarks
2.5 per cent indole-butylic acid lanolin applied to cut style	42	0	0	_____
5.0 per cent indole-butylic acid lanolin applied to cut style	17	0	0	_____
2.5 per cent indole-butylic acid paste to stigma	11	0	0	_____
Check, no treatment except emasculation	15	0	0	_____
Cut style only	7	0	0	_____
Pollen applied to cut style	7	0	0	_____
Lanolin paste applied to cut style	10	0	0	_____
2.5 per cent N.A.A. paste applied to cut style	10	8	80	7 of them died at about 1½ inch diameter
5.0 per cent N.A.A. paste applied to cut style*	15	3	20	Fruit small and odd shape
2.5 per cent N.A.A. paste applied to cut style*	12	4	33	_____
1.0 per cent N.A.A. paste applied to cut style*	11	4	36	_____
Self-pollinated*	10	0	0	_____
Stigma sprayed with 0.05 per cent N.A.A. solution*	2	2	100	Treated very late in the season

\*The seeds for these plants had been soaked in a 0.4 per cent colchicine aqueous solution for 4 days at room temperature.

induced to set by treating the cut style in all concentrations of lanolin paste and also in aqueous solution. These watermelons were perfectly seedless but they varied in shape. In general, all of the fruits were slightly triangular or even ribbed. Some, however, were normal in shape and size (Fig. 3A). The texture of these fruits was very solid and firm and the red coloration intense. No difference in flavor could be detected when compared with normally pollinated fruits.

The three plants of the Winter Sweet watermelon grown from seed which had been subjected to colchicine treatment before planting showed a typical colchicine effect, *i.e.*, stunting early in the season, large size of leaves and flowers and great vigor later in the season.



FIG. 2. Watermelons. A typical pair of colchicine-treated plants. The small fruit was from self-pollination; the large one was treated with 1 per cent naphthalene acetic acid lanolin paste. Both treated at the same time. The one from selfing dropped within 10 days, but the hormone-treated fruit continued to grow until maturity.

Although pollen was present in great abundance, it failed to induce fruit-set when the blossoms were selfed. On the other hand, hormone treated flowers set very satisfactorily. Nevertheless, fruits containing apparently normal seeds were formed from some open-pollinated flowers (Fig. 3B). This is believed to have been due to fertilization by pollen from nearby non-colchicine treated plants. These fruits were much smaller in size and slower in growth than those from the hormone-

treated blossoms.

Twenty-four fruits out of 25 blossoms treated were obtained on the Harris Wonder variety of pepper from the use of 1 per cent N. A. A. paste on cut styles (Fig. 4A). When the stigmas were sprayed with 0.05 per cent aqueous solution, four treated blossoms all set. Among seven flowers the styles of which were cut but given no other treatment, four set fruits which were seedless. Normally, untreated flowers set fruit with normal seeds (Fig. 4B). These treatments were started very late in the season and all the plants were killed by frost before the fruits were able to reach full maturity. However, all partly grown, hormone-treated fruits were seedless and perfect in shape.



FIG. 3. Watermelon. A, Longitudinal section of naphthalene acetic acid treated watermelon; B, A cross section of natural pollinated watermelon of the same variety.



FIG. 4. Pepper. A, From naphthalene acetic acid-treated blossom; B, From natural-pollinated pepper. No seeds were present in the hormone-treated fruit.

#### ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Dr. R. P. Hibbard of the Botany Department for supplying hormones, to Mr. H. L. Seaton of the Horticultural Department for many of the plants for this experiment and especially to Dr. A. F. Yeager for his constant encouragement, the opportunity to carry out this study and helpful criticism of the manuscript.

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## Natural Crossing in Beans at Different Degrees of Isolation

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**B**OTH the common bean (*Phaseolus vulgaris*) and the lima bean (*P. lunatus*) are usually classed as highly self-pollinated species. Kooiman (1) has reviewed the literature on natural crossing in the common bean. Various degrees of natural crossing, some as high as 10 per cent and others as low as 0 per cent, have been reported, but most experiments have indicated that natural crossing between varieties grown in adjacent rows varies between 0.5 and 2 per cent. In a more recent paper Mackie and Smith (2) have reported less than 1 per cent to occur between adjacent rows. Nevertheless, they believe that natural hybrids are an important source of rogues in seed crops of both the common and lima bean varieties. Few experiments on the degree of natural crossing in the lima bean have been reported; however, it is generally agreed that they are highly selfed.

Seed crops and stock seed plantings of different varieties of beans are often grown in adjoining plots separated by two rows planted to some other species. A tall growing crop is usually planted in the separating rows for the purpose of reducing the hazard of mechanical mixtures at the time of harvest. In breeding operations the progeny of individual plant selections are usually grown in adjacent rows. Only in the case of genetic studies, for the most part, have attempts been made to prevent natural crossing by caging or isolation.

The writer has had occasion to observe bean-breeding and seed-growing operations in California and Pennsylvania prior to taking up his present bean-breeding work at the Alabama Agricultural Experiment Station. It is believed that bumblebees and thrips, both of which have been mentioned in the literature as being largely responsible for natural crossing in *Phaseolus*, are far more numerous at Auburn, Alabama, than in the other areas mentioned. As no experiments on the degree of natural crossing in beans have been reported by southern workers it was considered worth while to determine how much natural crossing occurs under southern conditions.

Preliminary experiments conducted in 1936 revealed 2.70 per cent of natural crossing between two dwarf or bush varieties of the common bean, while 5.11 per cent of crossing occurred between two varieties of the pole type. These results showed a higher degree of natural crossing than the average reported in the literature, indicating the possibility that more crossing may be expected under southern conditions.

Obviously, as much as 2.70 per cent of natural crossing between plants in adjacent rows would be upsetting to a breeding program aimed at developing pure lines. It is seldom practical to isolate numerous progeny rows to a considerable distance from one another, especially when comparisons are to be made between the various progeny. Therefore, experiments were planned for the purpose of determining

*to what degree natural crossing in the common bean and lima bean can be reduced by limited isolation.*

### EXPERIMENTAL METHODS AND RESULTS

Contrasting variety pairs of both the lima bean and the common bean were grown in rows 1 yard, 2 yards, 3 yards, 5 yards and 9 yards apart. In every test the male variety or the one carrying the dominant "tester" gene was grown at an equal distance on each side of the female or recessive variety. The rows separating the experimental plantings were not left blank but were sown to cowpeas in the lima bean plot and to summer squash in the common bean plot.

The commercial varieties, Henderson's Bush and Sieva, were chosen for the lima bean tests. The vining habit of Sieva is dominant to the dwarf habit of Henderson's Bush, so the latter variety was used as the female parent. Seed was harvested from Henderson's Bush and planted in the field the following year when the per cent of plants exhibiting the vining habit of the male parent was determined. Commercial seed of Henderson's Bush is ordinarily free from vining rogues; however, the rows of this variety grown between rows of Sieva for the natural crossing tests were carefully checked to make sure that all plants were dwarf. The utmost care was exercised in harvesting and storing the seed. Consequently, there can be little doubt that any vining plants that occurred in the test crop were due to natural crosses with Sieva.

The Alabama No. 1 and Alabama No. 18 strains of pole beans were chosen for the common bean tests. Alabama No. 1 is darkly pigmented with anthocyanin in the stems, leaves, and pods. The pigmentation may be seen in the veins and petioles of the first true leaves. Alabama No. 18 is lightly pigmented showing little or no anthocyanin in the veins and petioles of the first leaves. Pigmentation of the stems of Alabama No. 18 seedlings is much lighter below the hypocotyl and does not extend above it as in Alabama No. 1. As this dark pigmentation is dominant to light pigmentation, natural crosses (between Alabama No. 18 as the female and Alabama No. 1 as the male) can be readily distinguished in the seedling stage. Alabama No. 18 is believed to have arisen as a gene mutation from Alabama No. 1 and is similar if not identical to it in genotype other than for the genes controlling anthocyanin pigmentation. Because of their similar genotype the two varieties bloom during the same period, and it is improbable that any cross-incompatibility exists between them. It seems reasonable to assume that the opportunity for the occurrence of natural crossing in the common bean is at its maximum between these strains. In the natural crossing plots, Alabama No. 18 was carefully observed soon after emergence, and an occasional darkly pigmented seedling, probably caused by previous natural crossing between seed plots, was removed. Because of the probable occurrence of recessive mutations from the darkly- to lightly-pigmented condition, the question has been raised as to whether a portion of the pigmented plants observed in the test might not be due to the reverse dominant mutation. Such is possible; however, in a recent seed crop of Alabama No. 18, less than 0.1 per cent of darkly



pigmented rogues were found. Even if this dominant mutation did occur at the rate of 1 in 1,000 the results of these tests would not be materially affected.

The results of these experiments are presented in Table I. It will be noted that 5.03 per cent of natural crossing was recorded for the lima beans grown in adjacent rows 1 yard apart. This is relatively high for a supposedly self-fertilized species and indicates that both in genetic studies and in pure-line breeding steps should be taken, under southern conditions, at least, to reduce the amount of natural crossing by some form of isolation or protection against insects. A reduction to 2.51 per cent was obtained by separating the varieties by 2 yards, but slightly less reduction was noted for the 3-yard separation. The 5-yard separation gave only a small further reduction of doubtful significance. With 9 yards isolation the amount of natural crossing was reduced to 1.10 per cent which is less than half that obtained at 5 yards.

In the experiment with common beans 8.25 per cent of natural crossing was recorded between Alabama No. 1 and Alabama No. 18 when grown in adjacent rows. Little reduction was obtained by allowing an additional yard between rows, but an appreciable decrease was noted between 2 and 3 yards separation. Little difference was noted in the next step to 5 yards, but at 9 yards the natural crossing was reduced to 2.63 per cent.

TABLE I—DEGREE OF NATURAL CROSSING BETWEEN ONE VARIETY PAIR EACH OF THE COMMON BEAN AND LIMA BEAN AT DIFFERENT DEGREES OF ISOLATION

Yards Between Dominant and Recessive Varieties	Total Plants in Test Planting	Number Showing Dominant Trait	Per Cent of Natural Crossing
<i>Lima Bean</i>			
1	1,710	86	5.03
2	1,916	48	2.51
3	1,606	52	3.24
5	1,671	38	2.27
9	1,460	16	1.10
<i>Common Bean</i>			
1	1,428	118	8.26
2	1,436	108	7.52
3	1,184	58	4.90
5	1,297	62	4.78
9	1,291	34	2.63

### DISCUSSION AND CONCLUSIONS

Although there was no gradual decrease in the degree of natural crossing proportional to the increasing isolation distances, a rather consistent reduction was noted with the exception of an increase from the 2-yard to the 3-yard test in lima beans. Separations of 3 and 5 yards proved effective in reducing natural crossing in both species. In both the lima bean and the common bean tests a reduction, which it seems reasonable to consider highly significant, was obtained by isolating rows 9 yards from one another. Further tests, using different variety pairs, must be conducted before conclusions may be safely drawn as to the value of different degrees of isolation under varying

conditions in reducing natural crossing. In the light of these experiments, however, it appears that natural crossing can be materially reduced by isolation of a few yards.

In view of the relatively high degree of natural crossing obtained in these experiments it would seem advisable, under conditions at Auburn, Alabama, at least, to isolate progeny tests from one another. This practice would be especially important in the final stages of selection when every effort should be made to establish homozygous lines.

In these tests the degree of natural crossing, even with 9 yards isolation, was relatively high for species ordinarily considered self pollinated. In handling foundation stocks and selections made for the purpose of purifying strains it would appear advisable at Auburn and possibly elsewhere in the South to give isolation even greater than 9 yards. The writer has adopted the policy of handling beans as a cross-pollinated species in the production of stock seed by allowing isolation of 50 yards or more. Further experiments may indicate just what degree of isolation must be allowed to reduce natural crossing to a minimum.

It will be noted that the degree of natural crossing recorded between adjacent rows of Alabama No. 1 and Alabama No. 18 beans was 8.26 per cent while preliminary tests with other variety pairs gave 2.70 per cent and 5.11 per cent, respectively. Subsequent tests with other varieties of common beans gave results ranging from 0.91 per cent to 6.20 per cent. These experiments confirm observations of other workers that the degree of natural crossing varies considerably with varieties. Crossing between Alabama No. 1 and Alabama No. 18 is probably greater than would occur between most variety pairs, yet the tests with other varieties indicate that natural crossing in adjacent rows averaged considerably higher at Auburn, Alabama, than at any other location from which similar data have been reported. It is possible that an equally high degree of natural crossing would be found to occur elsewhere in the South.

These data suggest that breeders of the self-fertilized crops should determine the amount of natural crossing which normally takes place under their conditions as an aid in deciding whether or not limited isolation is of value in reducing natural crossing to the minimum.

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# Polyploidy in Lettuce Induced by Colchicine

By ROSS C. THOMPSON and WILLIAM F. KOSAR, U. S. Horticultural Station, Beltsville, Md.

IN recent years cytologists and geneticists have been interested in various agents capable of influencing cell division in plants. There has been a special interest in such agents as high and low temperatures, x-ray, and various chemical substances capable of preventing the normal movement of the chromosomes to the poles following metaphase, resulting in cells having chromosomes in some multiple of the original number for the particular species. Recent reports showing that the alkaloid colchicine is an effective agent in inducing polyploidy in certain plants has greatly stimulated research in this field.

Blakslee and Avery (1) and Nebel and Ruttle (6) were among the first to report on the cytological and genetical significance of colchicine when applied to plant tissues. Derman (2), working with *Rhoeo discolor*, has presented results of a comprehensive cytological study of the role of colchicine in cell division. Other recent investigations on the effects of colchicine on division in plant cells have been made by Eigsti (3), Kostoff (4), Levan (5), Shmuck (7), and Walker (8,9).

Soon after the first reports were made on the influence of colchicine in inducing polyploidy in plants some studies were started by the writers at the United States Horticultural Station, Beltsville, Maryland, to determine the effectiveness of colchicine in producing polyploidy in lettuce, *Lactuca sativa*.

The present paper is a report of the results obtained from certain phases of these investigations.

## METHODS

In the initial studies lettuce seed of the variety Grand Rapids was placed in a .1 per cent solution of colchicine under conditions favorable for germination. At intervals of  $\frac{1}{2}$ , 1,  $1\frac{1}{2}$ , 2,  $2\frac{1}{2}$ , 3, 19, 21, 23, 27, and 48 hours a portion of the seed was removed from the solution and planted in flats. The seed was covered with muck. The growth processes were greatly checked by the treatment, especially root growth. Very few roots had developed on any of the treated embryos after more than 2 weeks in the muck. Enough of the muck was then removed to expose the growing point to light and air. After the seedlings had developed a few leaves they were transplanted to other flats and later to 10-inch clay pots in which they were grown to seed production.

Due to the retarding effect of colchicine on growth processes, especially the radicle when the seed treatment method was used, an effort was made to find some more favorable method of treating.

In later treatments the seed was germinated on filter paper in Petri dishes in darkness. The dishes were left in the dark in a germinator for a short time (12 to 24 hours) after germination, during which time the hypocotyls of the developing embryos became very much elongated due to the absence of light. By this time the rootlets had attached themselves to the paper sufficiently to permit the dishes to be inverted with-

out the embryos becoming detached from the paper. The inverted filter paper with the embryos attached to the under surface was carefully placed over a Petri dish of slightly less diameter than the filter paper and which contained .1 per cent colchicine to a depth of approximately 1 cm. By handling in this manner only the epicotyls and cotyledons of the embryos were in contact with the colchicine solution. The seedlings were left inverted in the solution for from 4 to 6 hours, washed off in tap water, and returned to their normal position. The filter paper with the seedlings attached was then placed in a Petri dish and a small amount of water added. After 16 to 20 hours in the water the seedlings were again inverted in the colchicine solution for 4 to 6 hours. After the second treatment with colchicine the plants were again washed in water and placed in a Petri dish in their normal position and a small amount of indolebutyric acid in a concentration of 1 ppm was applied to the filter paper. After about 4 hours in the indolebutyric acid the seedlings were removed from the paper, washed, and set in soil in planting flats.

Colchicine-treated seedlings that had their roots treated with indolebutyric acid have started off more rapidly when set in the soil than seedlings not treated with this material. It is difficult to treat small seedlings with colchicine without some of the solution coming in contact with the roots. The indolebutyric acid treatment seems to help to compensate for the retarding effect of colchicine.

In addition to the seedling treatment, the growing points on older plants have been treated with colchicine by various methods. Lateral and terminal buds have been treated by wrapping the buds with absorbent cotton and keeping the cotton saturated with .1 per cent colchicine for various periods of time. Terminal buds have been immersed in the solution in small vials. Lateral buds in the axils of the leaves have been treated by placing a drop of the solution in the angle formed between the main axis and the leaf petiole, completely covering and surrounding the bud with colchicine. The drop of solution was permitted to evaporate on the bud. A drop of the solution has been placed in the flower head after pollination and before the heads had closed.

In all of the studies so far made, .1 per cent aqueous solution of colchicine has been used, as the early treatments showed this to be an effective concentration for lettuce tissues.

## RESULTS

Approximately 200 seedlings were grown from the first seed treatment series. Of these, three showed abnormal leaf and flower characters at maturity. The leaves were smoother, lacking some of the savoying and marginal frilling characteristic of the normal plants for the Grand Rapids variety. Cytological examination of the pollen mother cells of these three plants showed them to be tetraploids having 18 gametic chromosomes. These three plants were all from the 27 hour treatment.

Only a few seed set on the three tetraploid plants. A small population was grown from the seed from each. All of the progenies were tetraploid as indicated by the morphological characters of the plants

and by cytological examination of the pollen mother cells. Like the original treated plants the  $F_1$  progenies were highly self-sterile. Individual plants varied greatly in this respect. Many heads set no seed. Some of the heads on the most fertile  $F_1$  plants set a maximum of six seeds where normal diploids set from 15 to 20 seed per head. The fact that some of the  $F_1$  progenies were much more fertile than the original colchicine-treated parents gives some hope that fairly fertile lines may be selected from future generations.

An odd situation occurred among the progenies grown from the seed of the three original colchicine-treated tetraploid plants. While they were all tetraploids, there was considerable variation among the individual plants. In one population there were three very smooth-leaved plants. The leaves were nearly free of the savoying and frilling characteristic of the normal diploids. None of these three plants set any seed. The individual plants varied greatly in growth rate and time of seed-stem development. One plant was more than 3 weeks later in developing a seed stem than the other tetraploids and diploids of the same age grown under the same conditions. Numerous other variations were observed among the progenies from the original tetraploids. These variations are difficult to explain. It has been generally reported that colchicine functions only in preventing the chromosomes from separating and moving to the poles following metaphase, resulting in cells having some multiple of the haploid number for the species. The normal arrangement of the genes is not believed to be effected by colchicine.

The variation observed among progenies from the original colchicine-induced tetraploid lettuce plants seems to indicate that the normal behavior of the genes may in some cases be influenced by the colchicine treatment. The appearance of the smooth-leaved sterile forms and the high degree of sterility in all of the progenies indicates some abnormal gene complex. The original material used for these studies was grown from seed of a strain of the Grand Rapids variety that is known to have been inbred for a great number of generations over a period of 20 years and probably is as homozygous as any strain of lettuce available. The variations appearing in the progenies from the original colchicine-induced diploid plants can hardly be attributed to heterozygosity in the original strain. The explanation of these variations has yet to be determined.

### DISCUSSION

The results so far obtained indicate that it will not be difficult to obtain polyploids in *Lactuca* by colchicine treatment of embryos and small seedlings. The treatment of older tissues has not been so promising. In most cases where growing points of older plants have been treated with colchicine, abnormal tissue develops for some time following the treatment but the diploid cells that escaped the effects of the chemical, outgrew the affected cells and the seed produced has in every case been diploid.

Due to the particular variations in chromosome numbers among the *Lactuca* species, the use of colchicine in building up the chromosome number of different species to permit pairing in mitosis does not seem

promising. However, colchicine may be of value in overcoming self-sterility in some of the interspecific hybrids that have been obtained.

At the present time the most promising use of colchicine in lettuce breeding appears to be in the production of autopolyploids. The tetraploid strain of Grand Rapids lettuce which has been obtained by the use of colchicine is much larger in leaf and frame than the normal diploid. The dwarf segregates in some lines of hybrid breeding material are the best heading types, but are too small to be satisfactory commercial strains. Tetraploidy induced by colchicine would be a valuable accomplishment in the case of dwarf segregates, providing we can increase their size and, at the same time, keep their many desirable characteristics.

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## Progress in Breeding Cucumbers Resistant to Scab (*Cladosporium cucumerinum*)

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**A** REPORT of early work on this project has been published in the Proceedings of this Society (1). Further work on the problem has contributed considerable information which will be published in detail at a later date.

In addition to the 22 American varieties tested for resistance and reported previously six new American varieties, eight varieties from England, one from Germany, 14 *Cucumis sativus* introductions from Brazil, 13 from India, and 11 from Turkey have been subjected to artificial inoculation tests for resistance in the seedling stage. None of this material has exhibited significant resistance.

The genetics of resistance in the resistant inbred lines and crosses reported previously has been studied in later selfed generations. Accumulated data support the earlier mentioned hypothesis that monogenic inheritance is involved in major resistance in this material. The degree of resistance has been found to vary to a minor extent in crosses, thus indicating that there may be secondary factors influencing the degree of resistance. These minor differences are not sufficiently clear-cut to be readily analyzed genetically. Resistance appears to be somewhat incompletely dominant to susceptibility. The resistant seedlings in segregating  $F_2$  populations have been classified into "homozygous resistant" and "heterozygous resistant" phenotypic classes; these individuals were self pollinated and subsequently tested for segregation in the next generation. Twenty-six progenies were tested and in 17 cases the parental plants were classified correctly which would suggest incomplete dominance.

A search for physiologic strains of *Cladosporium cucumerinum* in Maine has been made. Eighteen cultures of the pathogene were made from an equal number of infected fruits collected in widely separated locations in the State. Seedlings of resistant inbreds and susceptible varieties were inoculated with each of the strains. One proved to be non-pathogenic. No significant difference in pathogenicity of the other 17 could be demonstrated. That troublesome physiologic strains of the disease do not occur in New England is further indicated by reports from growers of Maine No. 2, a selection recently released for home garden use. In 55 reports concerning Maine No. 2, 46 growers reported "no scab", eight a "trace", and one "considerable". Circumstances surrounding this one report will be further studied. Concerning other varieties which were grown by these same gardeners the reports are quite different. In 41 reports only eight indicated "no scab", nine reported a "trace", eight reported "medium", and 16 reported "considerable". In other words, only 19.5 per cent reported no scab on their commercial varieties while 83.6 per cent indicated that Maine No. 2 was free from scab in their gardens.

A study of the genetic linkage relation of resistance to other plant and fruit characters is in progress but mathematical values have not been established as yet. Observations and data obtained thus far indicate that resistance is either independent of, or so loosely linked with spine and fruit color, fruit shape, and size of fruit as not to interfere seriously in practical breeding.

Some progress has been made in breeding commercial resistant types. One selection, Maine No. 2, which has black spines, short to medium fruits, and midseason in maturity has been released as a home garden variety. Reports from growers indicate that this selection is satisfactory for home garden use but unsatisfactory for market. More promising selections are under trial to meet this latter need.

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# Inheritance of the Immature Fruit Color of Peppers

By M. L. ODLAND and A. M. PORTER, *Connecticut State College, Storrs, Conn.*

**M**ANY peppers, belonging for the most part to the bell group, which are grown for stuffing, for salads, and so on, are marketed while still immature, although of full size, or nearly so. At this stage the fruit color of the pepper varies among varieties from a very pale green or sulphury white to a dark or cedar green. Some of the yellowish green varieties are called "yellow" varieties. In genetic and breeding material, extremely dark green and blackish green strains have been picked up. In general, the commercially important varieties are a cedar or box-wood green. However, some varieties are a lighter green and as a rule, there is considerable variation of color within varieties and strains. As considerable interest in the development of new varieties is at present being shown and as the immature fruit color might be considered a character of major importance, it seems desirable to obtain further information with regard to the inheritance of this character.

These immature fruit colors are, according to Webber (5) due to the chlorophyll pigments. Webber (5) and others (1, 2), have reported that green color in the immature fruit, is dominant to "yellow" with monohybrid segregation in the  $F_2$ . Odland (4) found sulphury white to be recessive to the several shades of green. His data indicate that immature fruit color is conditioned mainly by several factors each having a similar influence, that is, any pair in a dominant condition changes a sulphury white to a light green and the addition of any other pair in the dominant condition intensifies the green color. He designates the sulphury white as  $g_1 g_1 g_2 g_2 g_3 g_3 g_4 g_4$ ; the very dark green as  $G_1 G_1 G_2 G_2 G_3 G_3 G_4 G_4$  and the intermediate shades as  $G_1 G_1 g_2 g_2 g_3 g_3 g_4 g_4$  or  $g_1 g_1 G_2 G_2 g_3 g_3 g_4 g_4$ .

The immature fruit color may be, in some varieties, overcast with a purple color, which is, no doubt, due to an anthocyanin pigment. This paper is not concerned with the mature fruit color nor with this purple color, but rather reports a study of the inheritance of the chlorophyll color, with the medium green shades and "yellow" being given prime consideration.

## MATERIALS AND METHODS

Strains of "yellow" (Hungarian Yellow Wax and Tobasco), a strain of sulphury white (Ornamental), and strains of cedar green (Oshkosh and Red Cherry), were used in the study. These strains had been under observation, with controlled pollination, for several years and appeared to be homozygous for the characters in question. Ornamental, although not absolutely white, is sulphury white, a very light colored pepper. Tobasco is a yellowish lettuce green. Hungarian Yellow Wax is somewhat more yellow than Tobasco, being of a waxy yellow green color. The other two varieties are cedar green, a dark shade of green. Kosteer's color guide (3) was referred to determine the color.

In the spring of 1937,  $F_1$ ,  $F_2$  and backcross seed of the desired crosses was planted in the field together with the parent material. Seed for the  $F_2$  was, in all cases, saved from the same  $F_1$  plant that was used as a parent in the backcross. This procedure was followed because previous study (4) indicated that probably four or more factors conditioned the immature fruit color and, therefore, several years of inbreeding and selection would not insure that all of these factors were in a homozygous condition. By using a single  $F_1$  plant in the manner described the results obtained in  $F_2$  and the backcross would be comparable.

### EXPERIMENTAL RESULTS

In this study of the immature fruit color of the pepper, as in previous work (4) it was found to be extremely difficult to classify the color further than to separate the sulphury white, multiple recessive, from the various shades of green. Attempts were made to classify the various shades of green in  $F_2$  and this  $F_2$  classification agreed quite well with an  $F_3$  check. However, the classification is not reliable unless based on the  $F_3$  check. In all cases plants classed as sulphury white have bred true, consequently  $F_2$  results, as well as the backcross, if sufficiently large populations are grown, should give fairly reliable information.

*Sulphury White, Cedar Green:*—In Table I the results of crosses Ornamental x Red Cherry and Ornamental x Oshkosh are summarized. All plants with an immature fruit color other than sulphury white were placed in the column headed "green", that is, this column includes plants with immature fruit colors from a light lettuce green to cedar green. In the  $F_2$  culture 207.37 and in the backcross culture 402.38, agreement with 15 to 1 and a 3 to 1 ratios respectively was obtained. Likewise, in the  $F_2$  culture 203.37 and backcross culture 400.38, 15 to 1 and 3 to 1 ratios were obtained. In the backcross culture 401.38, which is a backcross to the dominant parent, no sulphury whites were obtained. Moreover, all of the resulting plants were as dark or darker green than the  $F_1$ , which was moss green, a color while intermediate between the parents indicates partial dominance of green. The results of this series of crosses agree quite well with the expected when two factors for immature fruit color are postulated.

*Sulphury White, Yellowish Green:*—The immature fruit color of the  $F_1$  of Ornamental x Hungarian Yellow Wax, or the reciprocal, was a shade lighter than the darker parent, dominance being not quite complete. This  $F_1$  as well as the darker parent was somewhat more yellow than the  $F_1$  of the cross reported in Table I. The data presented in Table II show that the  $F_2$  ratios (cultures 195.37, 198.37 and 223.37) agree quite closely to a 3 to 1 ratio, while the segregation in the backcross (cultures 396.38 and 399.38) to the recessive parent fits a 1 to 1 ratio. This is in agreement with an hypothesis of a single factor difference between sulphury white and yellowish green. In the backcross to the dominant parent no sulphury whites were obtained, a result that further supports the single factor hypothesis.

This particular cross was selected for study because information was

TABLE I—TEST OF AGREEMENT BETWEEN OBSERVED AND EXPECTED CLASS FREQUENCIES APPLIED TO SEVERAL  $F_2$  AND BACKCROSS CULTURES OF PEPPERS ON THE HYPOTHESIS THAT THE IMMATURE FRUIT COLORS INVOLVED SEGREGATE IN A DIHYBRID MANNER

Cross and Culture Number	Number of Plants	Immature Fruit Color				Deviation	Deviation* S. E
		Observed		Calculated			
		Green	Sulphury White	Green	Sulphury White		
Ornamental × Red Cherry F <sub>2</sub> 207.37	58	55	3	54.38	3.62	0.63	0.32
(Ornamental × Red Cherry) × Ornamental backcross 402.38	130	107	23	97.5	32.5	9.5	1.44
Ornamental × Oshkosh F <sub>2</sub> 203.37	201	187	14	188.44	12.56	1.44	0.39
(Ornamental × Oshkosh) × Ornamental backcross 400.38	35	24	11	26.25	8.75	2.25	0.38
(Ornamental × Oshkosh) × Oshkosh backcross 401.38	43	43	0	43	0	—	—

\*When Deviation was not greater than 2 the departure from expected was not considered significant.

desired with respect to the "yellow" color. As the data and discussion indicate, clear cut segregation of the sulphury white and green ("yellow") was found. All, or at least a high per cent of the green segregates, were a yellow green like the "yellow" parent. No information was obtained as to whether or not a modifying factor caused these to be yellowish green; or if, possibly, the particular pair of allelomorphs that conditioned the color of the Hungarian Yellow Wax tended to cause a yellowish green color rather than a pale or lettuce green such as obtained from crosses like those reported in Table I.

*Lettuce Green, Sulphury White:*—The color of the immature fruit of the particular strain of Tobasco used in this cross was not a decided yellow like the Hungarian Yellow Wax, being only slightly more yellow than the intermediate segregates from crosses like those described in Table I. No definite information in regard to the "yellow" color was obtained from this cross.

The data on the green color are given in Table II. The  $F_2$  (culture 210.37) segregation agrees quite well with a 3 to 1 ratio, while the backcross to the recessive parent (culture 394.38) agrees very well with a 1 to 1 ratio indication a single factor difference. In the backcross to the dominant parent (culture 392.38 and 393.38) no sulphury white plants were obtained which is also in agreement with a single factor hypothesis.

*Yellowish Green, Cedar Green:*—Data obtained from a cross between Oshkosh and Hungarian Yellow Wax are presented in Table III. The  $F_1$  was almost as dark in color as the Oshkosh indicating partial dominance of the darker color. From the data summarized in Tables I and II a single factor difference might be suspected in this cross. Segregation in the  $F_2$  was not clear cut; however, three classes, yellowish green (light green), the  $F_1$  color (medium green), and

TABLE II—TEST OF AGREEMENT BETWEEN OBSERVED AND EXPECTED CLASS FREQUENCIES APPLIED TO SEVERAL  $F_2$  AND BACKCROSS CULTURES OF PEPPERS ON THE HYPOTHESIS THAT THE IMMATURE FRUIT COLORS, LIGHT GREEN (YELLOWISH OR LETTUCE) AND SULPHURY WHITE, SEGREGATE IN A MONOHYBRID MANNER

Cross and Culture Number	Number of Plants	Immature Fruit Color				Deviation	Deviation <sup>1</sup> S. E.
		Observed		Calculated			
		Light Green	Sulphury White	Light Green	Sulphury White		
Ornamental X Hungarian Yellow Wax F <sub>2</sub> 195.37	82	64	18	61.50	20.50	2.50	0.48
Hungarian Yellow Wax X Ornamental F <sub>2</sub> 198.37	161	122	39	120.75	40.25	1.25	0.17
Hungarian Yellow Wax X Ornamental F <sub>2</sub> 223.37	273	199	74	204.75	68.25	5.75	0.60
(Ornamental X Hungarian Wax) X Ornamental backcross 396.38	165	89	76	82.50	82.50	6.50	0.51
(Hungarian Yellow Wax X Ornamental) X Ornamental backcross 399.38	90	51	39	45.00	45.00	6.00	0.63
Ornamental X (Hungarian Yellow Wax X Ornamental) backcross 406.38	7	4	3	3.50	3.50	0.50	0.19
Hungarian Yellow Wax X (Ornamental X Hungarian Yellow Wax) backcross 411.38	—	71	—	71.00	—	—	—
(Hungarian Yellow Wax X Ornamental X Hungarian Yellow Wax) backcross 398.38	—	316	—	316.00	—	—	—
Tabasco X Ornamental F <sub>2</sub> 210.37	168	119	49	126	42	7	0.94
(Tabasco X Ornamental) X Ornamental backcross 394.38	22	10	12	11	11	1	0.21
(Tabasco X Ornamental) X Tabasco backcross 392.38	110	110	0	110	0	—	—
Tabasco X (Tabasco X Ornamental) backcross 393.38	12	12	0	12	0	—	—

\*When Deviation was not greater than 2 departure from expected was not considered significant. S. E.

cedar green (dark green) were more or less arbitrarily set up. The demarcation between the yellowish green and the other two classes was fairly clear. The results are given in Table III. The  $X^2 = 1.637$  shows good agreement between observed and the expected 1:2:1 ratio, suggesting that the difference in immature fruit color is dependent upon a single factor pair in this cross.

TABLE III—TEST OF AGREEMENT BETWEEN OBSERVED AND EXPECTED CLASS FREQUENCIES APPLIED TO AN  $F_2$  CULTURE OF A CROSS BETWEEN OSHKOSH (CEDAR GREEN) AND HUNGARIAN YELLOW WAX (YELLOWISH GREEN) WHERE A 1:2:1 RATIO WAS EXPECTED

Culture Number	Number of Plants	Immature Fruit Color						X <sup>2</sup>
		Observed			Calculated			
		Dark Green	Medium Green	Light Green	Dark Green	Medium Green	Light Green	
223.37	66	12	36	18	16.5	33.0	16.5	1.637

\*With 2 degrees of freedom  $X^2 = 5.991$  for the 5 per cent point.

## DISCUSSION AND CONCLUSIONS

The lettuce or yellowish green color of the Hungarian Yellow Wax and Tobasco was found to be dominant to the sulphury white of Ornamental, and recessive to the cedar green of Oshkosh and Red Cherry. A single pair of major factors differentiates the colors in both cases. Cedar green of Oshkosh and Red Cherry was found to be dominant to sulphury white of Ornamental with two major factors differentiating the colors.

These results are in general agreement with previous work (4) which indicated that the immature fruit color was conditioned by a series of factors, ( $G_1 g_1 G_2 g_2 - G_n g_n$ ).

The following genotypes might be assigned to the several colors of the immature fruit of peppers, sulphury white =  $g_1 g_1 g_2 g_2 - g_n g_n$ , lettuce green =  $G_1 G_1 g_2 g_2 - g_n g_n$  or  $g_1 g_1 G_2 G_2 - g_n g_n$  (or any factor pair of the series in the dominant condition) and cedar green =  $G_1 G_1 G_2 G_2 - g_n g_n$  (or any two factor pairs of the series in the dominant condition).

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## Rest Period in Cucumber Seeds<sup>1</sup>

By VICTOR M. WATTS, *University of Arkansas, Fayetteville, Ark.*

**T**HE problem of rest period in cucumber seeds was encountered when freshly harvested seeds of breeding stock were planted during the winter of 1937. In about four-fifths of the plantings complete failures or very low percentages of germination resulted. Such failures, and the desirability of producing several generations in one year, led to the studies here reported.

Since the seeds that had been used had come from fruits that were not completely mature a study was made to determine the influence of maturity on the immediate germination of the seeds. Five slightly immature Black Diamond fruits, and five that were completely mature were selected. The immature fruits were pale green, with a noticeably yellow cast. The mature fruits were uniformly pale yellow. The seeds of the immature fruits were well filled, and in all respects resembled those from the mature fruits.

Lots of 100 seeds from each cucumber were planted  $\frac{1}{2}$  inch deep in 4-inch pots of clean sand, and the water supply was kept constant by maintaining  $\frac{1}{4}$ -inch of water in the saucers containing the pots. This procedure was followed in all subsequent tests involving sand as the medium for germination. In this test the temperature of the sand varied between 24 and 27 degrees C.

The percentages of germination recorded for the seeds from individual immature fruits were 3, 4, 6, 28, and 70; for the mature fruits they were 2, 4, 8, 30, and 84. It seems quite evident that the wide variation in immediate germination, seen in these results, was caused by some factor other than difference in maturity.

In order to determine the duration of the rest period, seeds from each of six mature Black Diamond fruits were divided into lots of 50. These were planted at intervals of 10 days, in moist sand the temperature of which was maintained at about 20 degrees C. The unplanted seeds were stored at a temperature of about 22 degrees C.

The seeds of two of the fruits in this test germinated at the rate of 80 and 94 per cent in the first planting, and the percentages secured in later plantings did not vary significantly from these figures. Initial germination of the four other lots varied from 2 to 22 per cent. In three of these the percentage of germination was gradually increased, in successive plantings, to reach maxima of from 85 to 98 per cent in the plantings made 40 days after harvest. In the case of the sixth lot 10 per cent of the seeds in the first planting germinated, and no significant change was noted in four subsequent plantings. In the sixth planting of this lot, made 50 days after harvest, 96 per cent of the seeds germinated. These results verify earlier observations to the effect that the rest period does not occur consistently and indicate that, in those cases where it occurs, it lasts from 40 to 50 days.

A preliminary attempt to find some method of breaking the rest period involved the use of seeds from a number of mature Black Dia-

<sup>1</sup>Research paper No. 639, Journal Series, University of Arkansas.

mond fruits. The seeds of all the fruits were thoroughly mixed and divided into lots of 100. In all of these tests the seeds were planted the day after they were harvested, and in all but one they were planted in sand at about 22 degrees C.

Ten per cent germination was recorded for each of two lots of untreated seeds. Seeds treated for 4 hours with the fumes of chloroform, ether, and ethyl-chlor-hydrin germinated at the rate of 4, 10, and 12 per cent, respectively. One-half millimeter was clipped from the scar ends of one lot, and 18 per cent germination was recorded for these seeds. Twenty-six per cent germination was recorded for seeds from which the seedcoats had been removed. One lot was placed on moist filter paper in a petri dish held at 30 degrees C. Sixty-four per cent germination was recorded in this case.

Since treatments involving peeling and planting on moist filter paper at 30 degrees C resulted in relatively high germination percentages in the tests just described, several tests including such treatments were conducted. Some of these tests also included treatments in which the embryos were wounded. In each test the seeds were taken from a single, fully matured fruit. In all tests except No. 5 duplicate lots of 50 seeds were used for each treatment, but since there was very little variation in results between duplicates, average percentages are reported. In the case of Test No. 5 single lots of 50 seeds each were used.

In Test No. 1 wounding was accomplished by cutting slits, about 1 millimeter long, in the ends of the cotyledons. In Tests No. 2 and 5 seeds were wounded by removing  $\frac{1}{2}$  millimeter from the ends of the cotyledons. In all petri dish plantings seeds were placed on  $\frac{1}{8}$  inch mats of moist shredded filter paper. The results of these tests are presented in Table I.

TABLE I—INFLUENCE OF SEED TREATMENTS, PLANTING MEDIA AND TEMPERATURE VARIATIONS ON THE GERMINATION OF NEWLY HARVESTED CUCUMBER SEEDS

Test Number	Seed Treatments	Planting Media	Temperatures (Degrees C)	Germination (Per Cent)
1	None	Sand	22	2
	Wounded	Sand	22	54
	Peeled	Sand	22	72
	Peeled, wounded	Sand	22	76
2	None	Sand	22	0
	Wounded	Sand	22	46
	Peeled	Sand	22	80
	Peeled, wounded	Sand	22	100
3	None	Sand	22	20
	None	Filter paper	22	92
	None	Filter paper	30	100
	Peeled	Filter paper	30	100
4	None	Sand	22	10
	None	Filter paper	22	18
	None	Filter paper	30	96
	Peeled	Filter paper	30	100
5	None	Sand	22	0
	None	Filter paper	22	6
	Peeled	Filter paper	22	73
	Peeled, wounded	Filter paper	22	80
	Peeled	Filter paper	30	90
	Peeled, wounded	Filter paper	30	95
	Peeled, wounded	Filter paper	30	95

In these tests, while germination of untreated seeds in sand varied from 0 to 20 per cent, peeling consistently resulted in the germination of over 70 per cent; wounding the embryos also resulted in increased germination; temperatures of 30 degrees C resulted in high percentages when compared to 22 degrees C; and planting in petri dishes on moist, shredded filter paper resulted in consistently higher percentages than planting in sand.

Seedlings started on shredded filter paper were transplanted to soil with no apparent damage when the move was made before the hypocotyls were 1 inch long.

The results that have been presented suggest, as a practical method of germinating newly harvested cucumber seeds, the use of some such absorbent material as shredded filter paper in a moist chamber at 30 degrees C. The removal of seed coats was of considerable value, and should prove practical for such small lots of seeds as are frequently used in breeding work.

#### CONCLUSION

Although considerable variation was noted in the germination percentages of seeds from freshly harvested cucumbers, in most cases low percentages followed planting of freshly harvested seed. In this study this variation was not associated with the degree of maturity of the fruit at harvest, and the rest period, when it occurred, lasted from 40 to 50 days. Germination of new seed was improved by planting on moist absorbent material, in a moist chamber at 30 degrees C, and by removal of the seed coats.



# A Study of Rapid Deterioration of Vegetable Seeds and Methods for its Prevention<sup>1</sup>

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**I**N warm humid regions such as our Gulf Coast, the percentage germination and viability of some vegetable seeds decrease seriously between shipment of the seed to the local dealer and the time of sowing by the farmer, although only a few weeks may intervene. Appreciable losses in viability may occur within the normal range of successive plantings within a single season, if storage conditions are adverse.

Several investigators have shown for various seeds that if either the humidity or temperature of storage is high, the other must be low, if viability is to be preserved. However, the comparative behavior of different vegetable crop seeds all stored at identical and known humidities and temperatures for numerous successive time intervals, is almost totally unknown. These studies were designed to yield definite figures on 10 kinds of seeds, as a basis for predicting their probable behavior when stored for different lengths of time under a variety of conditions.

## MATERIALS AND METHODS

In June 1938, good commercial stocks of the 1937 crop of the following seeds were placed under the conditions described below: Henderson Bush lima bean, Bountiful bean, Narrow Grain Evergreen sweet corn, Detroit Dark Red beet, All-Seasons cabbage, Chantenay carrot, Yellow Bermuda onion, Long Standing Bloomsdale spinach, Bonny Best tomato, and freshly shelled Spanish 18-38 peanut. Moisture determinations and viability tests were made when the experiment was set up. The experiment was designed to be analyzed by the variance method.

Both at 80 and at 50 degrees the seeds were placed in high (78 and 81 per cent), medium (66 per cent) and low (44 and 51 per cent) relative humidity chambers, with humidity adjusted by calcium chloride. Seeds were also placed in a screened cage in an unheated warehouse to approximate ordinary commercial storage. On June 25, 11 accurately weighed samples of each kind of seed were placed at each of the seven storage conditions, each sample in an individual shallow, open container. At 10-day intervals for 110 days, one container of each kind of seed was removed from each chamber, weighed, mixed, samples drawn for moisture, and viability determinations, the residue weighed and stored at 32 degrees F. Beans, peanuts and corn were germinated in soil in the greenhouse in duplicate 100-seed lots. The other seeds were germinated in quadruplicate 100-seed lots by standard laboratory methods in accurately controlled chambers. Moisture was determined by drying 24 hours at  $100 \pm 0.5$  degrees C.

Wet and dry bulb temperatures were read twice daily for all condi-

<sup>1</sup>A condensed and preliminary report. The complete data will be published by the U. S. Department of Agriculture.

tions. Temperature control was good, and humidity was fairly well controlled at low temperature. Difficulty was encountered in holding the high and low humidities at the proper levels in the 80 degrees F room where humidities varied from 75 to 84 per cent with a mean of 78 in the "high" chamber, 64 to 70 per cent with a mean of 66 in the "medium" humidity chamber, and 40 to 50 per cent with a mean of 44 in the "low".

In addition to the samples mentioned above, two bags of each kind of seed (0.5 to 2.0 kg, depending on size of seed) were weighed and placed in each chamber. Certain of these were withdrawn at irregular intervals, weighed, and samples drawn for moisture and viability determinations. The remainder of each bag was then halved, one part being dried to its proportionate original weight in a current of air in a drying "tunnel" at 120 degrees F, and the other at 150 degrees F. Samples were then drawn from the dried seed for moisture and viability determinations.

### RESULTS

The original data involve up to the present time some 3,000 temperature and humidity records, 1,000 changes in weight, 1,000 moisture determinations, and nearly 3,500 germination tests. These have been subjected to variance and covariance analysis to evaluate the significance of (a) differences in various responses to specific factors and their simpler interaction effects; (b) the correlations among environmental factors, physical changes, and viability; (c) series of regression values involving physical responses of each kind of seed to environment that should be of immediate practical value. Only the broader outlines of the results so far developed can be presented here, and all conclusions attempted have a statistically significant background in the data. The range in conditions and the time involved must be kept in mind.

*Changes in Seed Moisture and Weight:*—Major attention was devoted to effects of humidity and temperature upon rates of change in moisture content of the seeds and upon the moisture content each kind of seed reached at different humidities, because moisture content is known to be a very potent influence on keeping quality.

At 80 + per cent humidity the seeds absorbed water faster at 80 degrees than at 50 degrees, reaching equilibrium sooner. Each species developed its characteristic moisture level at each 10-day mean humidity with a high degree of consistency. Temperature (50 degrees versus 80 degrees F) was without important significant effect on the regression of moisture content on humidity. At 80 degrees and high humidity, increases in weight of seeds were less than expected on the basis of moisture percentage, indicating a loss of dry matter. At all other storage conditions, weight changes could be accounted for by moisture gained or lost.

Table I shows the mean humidities, weight changes, and moisture contents, together with coefficients of regression for each kind of seed, from which regression lines can be easily constructed. In estimating the value of seed moisture content at X any given level of air humidity, y is the mean seed moisture content shown in the second column;

$x = 64.44$ , the mean air humidity; and  $b$  is the regression coefficient shown in the third column. In estimating change in seed moisture for any given change in weight, use the values for  $x$ ,  $y$ , and  $b$  shown in the fifth to seventh columns of the table. Note the very marked differences among species in the change in percentage moisture content per unit change (1 per cent) in relative humidity.

Relative humidity is a much better index of what moisture content a known kind of seed will develop, than any other common measure of the moisture state of the air.

TABLE I—CERTAIN EFFECTS OF ATMOSPHERIC HUMIDITY UPON MOISTURE CONTENT OF STORED VEGETABLE SEEDS

Kind of Seed	Data on Moisture Content*			Data on Change in Weight and Moisture			
	Mean Seed Moisture Content (y)* Per Cent	Regression of Seed Moisture on Humidity†		Mean Change in Weight (x) Per Cent	Mean Change in Seed Moisture (y) Per Cent	Regression of Seed Moisture Changes on Weight Change†	
		Coefficient of Regression (b)	Error of Estimate (Per Cent)			Coefficient of Regression (b)	Error of Estimate (Per Cent)
Lima bean	12.18	.165	1.12	1.06	1.05	.876	.24
Kidney bean	11.81	.209	1.09	0.29	0.16	.896	.37
Sweet corn	10.97	.150	.79	-1.39	-1.09	.882	.37
Peanut	6.38	.099	.75	0.17	0.15	.875	.36
Beet	11.07	.214	1.19	0.88	0.94	.854	.92
Cabbage	8.01	.125	1.00	0.27	0.40	.870	.73
Carrot	9.89	.182	1.01	0.62	0.76	.914	.61
Onion	10.75	.162	.97	0.55	0.58	.760	.95
Spinach	11.98	.159	.74	0.58	0.60	.867	.20
Tomato	9.57	.128	.64	0.38	0.34	.857	.21

\*Mean air humidity,  $(x) = 64.44$ .

†Locate points on regression line by the usual regression equation:  $E = y + b(X - x)$

*Changes in Viability:*—The results on viability are expressed in terms of normal seedlings capable of continued strong development. As a result of deterioration in storage some kinds of seeds produced numbers of seedlings having insufficient vitality to develop normal plants.

At 80 degrees F and 75 to 80 per cent humidity, all seeds except beet, showed deterioration within 110 days; sweet corn, onion and spinach were practically destroyed within 60 days. These three fell below good "practical" standards in 20, 10, and about 15 days, respectively. Beans, cabbage and carrot seeds showed appreciable loss in 40 to 60 days, but remained above an arbitrary "practical" standard 70 to 80 days. Tomato showed a small, significant deterioration after 40 to 50 days, falling below a good planting standard after 90 days.

Table II shows how long each lot of seed under different conditions of storage remained capable of producing a reasonably high percentage of good strong seedlings.

In connection with Table II and the data in the text relative to rate of deterioration, the figures on mean percentage moisture in the seeds from the several storage conditions are of major importance. These percentages have been estimated for each kind of seed for the entire period in each chamber, and are presented in Table III.

TABLE II—SUMMARY OF CERTAIN RESULTS OF SEED VIABILITY TESTS  
SHOWING APPROXIMATE TIME REQUIRED AT VARIOUS STORAGE CON-  
DITIONS TO DECREASE TO ARBITRARY STANDARDS OF VIABILITY

Kind of Seed	Initial Viability (Per Cent)	Minimum Standard Viability* (Per Cent)	Days in Storage Condition Shown Required to Fall Below Arbitrary Standard						
			HH (Days)	MH (Days)	LH (Days)	HL (Days)	ML (Days)	LL (Days)	N (Days)
Lima bean . . . . .	80	70	70	70	70	90	..	..	70
Kidney bean . . . . .	97	80	80	110	110	..	..	..	..
Sweet corn . . . . .	82	70	20	50	80	60	..	..	50
Peanut . . . . .	83	70	15	50	80	50	..	..	60
Beet . . . . .	83	75	†	..	..	..	..	..	..
Cabbage . . . . .	93	80	70	..	..	..	..	..	..
Carrot . . . . .	92	75	90	..	..	..	..	..	..
Onion . . . . .	80	70	10	90	..	110	..	..	40
Spinach . . . . .	80	65	15	110	..	..	..	..	90
Tomato . . . . .	93	80	110	..	..	..	..	..	..

\*Percentage of seeds producing fully normal, strong, seedlings.

†Leads indicate that viability stayed above the arbitrary standard for the 110 days' duration of this short-time study.

TABLE III—MOISTURE CONTENT OF SEEDS HELD FOR 10 TO 110 DAYS UNDER  
DIFFERENT STORAGE CONDITIONS. (EXPRESSED AS MEAN PERCENTAGE  
OF MOISTURE CALCULATED ON FRESH WEIGHT BASIS)

Crop	Mean Moisture Content of Seeds Stored Under Conditions Shown*								
	HH (Per Cent)	MH (Per Cent)	LH (Per Cent)	HL (Per Cent)	ML (Per Cent)	LL (Per Cent)	N (Per Cent)	Mean (Per Cent)	Original Moisture† (Per Cent)
Lima bean . . . . .	15.6	11.3	8.8	14.6	12.2	10.6	12.1	12.2	11.1
Kidney bean . . . . .	15.4	10.8	7.4	15.4	11.8	10.0	11.7	11.8	11.6
Sweet corn . . . . .	12.9	10.3	7.5	13.7	11.6	9.8	10.7	10.9	12.0
Peanut . . . . .	8.2	5.6	4.3	8.2	6.2	5.6	6.2	6.3	6.1
Beet . . . . .	15.0	9.9	7.2	15.0	10.4	8.8	10.8	11.0	10.1
Cabbage . . . . .	10.1	7.3	5.9	10.5	7.8	6.4	7.8	8.0	7.6
Carrot . . . . .	12.6	9.0	6.5	13.6	9.8	7.9	9.7	9.9	9.1
Onion . . . . .	13.2	10.3	7.5	13.8	10.7	9.0	10.3	10.7	10.1
Spinach . . . . .	14.3	11.2	8.5	15.0	12.0	10.7	11.8	11.9	11.4
Tomato . . . . .	11.2	8.9	6.9	12.2	9.7	8.4	9.4	9.5	9.2
Mean . . . . .	12.4	9.2	6.8	13.2	9.9	8.7	9.7	10.4	9.8

\*The first letter of each column heading denotes humidity; high, medium, or low. The second letter denotes temperature; high or low. N represents natural conditions in the warehouse. See text.

†Moisture content of seed at the beginning of the experiment.

At 80 degrees F and medium humidity (66 per cent) sweet corn showed significant loss of viability at 40 days, kidney bean, peanut and onion at 50 to 60 days and lima bean at 80 days. Table II shows how long they held above the minimum standard. Spinach was the only other seed that showed a significant loss before 110 days.

At low humidity (40 to 50 per cent) at 80 degrees F both beans and peanut showed essentially the same response as at 66 per cent humidity. Sweet corn deteriorated less rapidly, requiring 50 to 60 days to show significant change. Even at low humidity a temperature as high as 80 degrees is definitely injurious to these three legumes and to sweet corn within 2 to 3 months.

At low temperature (50 degrees F) beans, sweet corn, peanut, and onion were the only seeds shown by these methods to lose viability within 110 days. There is some doubt about the validity of the results on lima bean and peanut. At high humidity, a temperature as cool as 50 degrees was definitely inadequate to prevent significant change in seedling rating of kidney bean, sweet corn and onion in about 70, 50, and 100 days, respectively. Fairly good planting quality was retained over 110 days by kidney beans, about 60 days by sweet corn and 100 days by onion. The loss in viability was accompanied by a corresponding increase of abnormal growths not considered as of value. No significant changes in total number of sprouts (including both strong and weak) were noted at low temperature.

At medium and low humidity at 50 degrees F significant decreases in rating of good seedlings of lima bean, sweet corn and spinach appeared at the 110 day test, but there were no significant decreases in total germination. Good evidence of deterioration to or below the arbitrary standard on this last date was lacking.

In warehouse storage the mean conditions for the 110-day period approximated those of the medium humidity chamber at 80 degrees F and the viability responses roughly paralleled those of seeds from 66 per cent humidity at 80 degrees F.

*Dehydration Studies:*—Seeds stored in bags in humid chambers were removed at intervals after they had developed a harmful moisture content, and dried as quickly as possible in currents of air at 120 degrees and 150 degrees F to determine if they could be restored to a safe moisture level without damage. If seeds have already suffered injury in storage, dehydration will of course repair no damage. It required 3 hours at 150 degrees F to reduce lima beans and kidney beans with high moisture to the moisture content shown at the start of the study, and 3 hours at 120 degrees F was generally 1 to 2 per cent short of the desired effect. This heating of bean seeds at 150 degrees F when they contained 14 to 16 per cent moisture produced serious injury, reducing germination 12 to 25 per cent. Three hours at 120 degrees F was without immediate effect on viability.

Peanut seeds containing 8 to 9 per cent moisture required  $1\frac{1}{4}$  to  $1\frac{1}{2}$  hours to be dried down to 5.5 to 6.0 per cent moisture, and most lots were practically ruined by the treatment.

Seeds from low humidity were given the same heating as those removed from high humidity chambers to determine the interaction of heat and seed moisture. Beans were uninjured but peanuts were injured, if they contained as much as 5 per cent moisture when heating started.

All other crops were effectively dried in 30 to 45 minutes at 150 degrees F or 30 to 60 minutes at 120 degrees F without significant immediate effect upon viability. Samples from all treatments were put in cold storage for germination at a later date.

Thus, sweet corn and the small seeds used can be dried quickly at 120 to 150 degrees F without immediate damage, but the large-seeded legumes cannot.

# Some Examples of Heterosis in the Cucumber, *Cucumis sativus* L. <sup>1 2</sup>

By A. E. HUTCHINS, *University of Minnesota, St. Paul, Minn.*

THE crossing of closely related varieties of plants often produces a first generation that is more vigorous than either parent. Such results have instigated many experiments to test the possibility of using such crosses commercially. Heterosis was first noted in the cucumber by Hayes and Jones (1) in 1916. They found that first generation crosses may frequently be expected to exceed the higher yielding parent in yield, that this heterosis may be manifested by increase in size of fruit or in number of fruits per plant, and that crosses between parents closely resembling each other may not exhibit heterosis. This paper is concerned with the reaction obtained in crosses between widely different cucumber varieties.

## MATERIALS AND METHODS

In 1937, crosses were made between the Mincu, a pickling variety, and a number of slicing varieties; the Straight-8, Davis Perfect, Long-fellow, Early Fortune, Shamrock, Arlington White Spine, Colorado, Japanese Climbing, and Improved Long Green. The Mincu, the parent used in all crosses, is a very early variety with small fruits and vines while the other varieties are later and have larger fruits and vines. In 1938 the F<sub>1</sub> populations derived from these crosses together with the parents were planted in four randomized blocks in the field, the plants spaced 3 by 6 feet apart, and data taken on yield per plant, fruit number per plant, and average weight per fruit. Fruits were harvested when they appeared to be of proper marketable size.

## EXPERIMENTAL RESULTS

Before discussing the results of individual combinations, the variance obtained for the important characters will be presented. The variance obtained for yield is given in Table I.

TABLE I—ANALYSIS OF VARIANCE OF THE YIELDS OF F<sub>1</sub> CUCUMBER PROGENIES AND OF THEIR PARENTS

Variation Due to	Degrees of Freedom	Mean Square
Varieties .....	24	1.37*
Blocks .....	3	0.27
Varieties by blocks .....	72	0.42
Harvest intervals .....	5	23.65*
Varieties by harvest intervals .....	120	1.18*
Remainder .....	375	0.31
Total .....	599	—

\*F values exceed the 1 per cent point.

<sup>1</sup>Paper No. 1668 of the Journal Series of the Minnesota Agricultural Experiment Station.

<sup>2</sup>Completion of certain parts of this paper was made possible by personnel of Works Progress Administration Official Project 465-71-3-350.

If the interaction of varieties by blocks is taken as an estimate of error for yield, it can be seen from the data presented in Table I that a significant difference in yield between varieties, which represent the parents and the  $F_1$  generations, was obtained. The large variance obtained between harvest intervals reflects the cyclic type of production obtained when the fruits are removed from the vines at regular intervals. That varieties reacted differently throughout the picking season is indicated by the variance obtained in the interaction of varieties by harvest intervals.

In Table II is presented the variance for the average number of fruits per plant and the average weight per fruit between varieties; varieties representing both parents and  $F_1$  generations.

TABLE II—ANALYSIS OF VARIANCE OF THE AVERAGE NUMBER OF FRUITS PER PLANT AND THE AVERAGE WEIGHT PER FRUIT OF  $F_1$  CUCUMBER PROGENIES AND THEIR PARENTS

Variation Due to	Degrees of Freedom	Mean Square	
		Average Number of Fruit	Average Weight per Fruit
Varieties . . . . .	24	39.74*	0.027*
Blocks . . . . .	3	3.35	0.004
Error . . . . .	72	9.24	0.003
Total . . . . .	99		

\*F value exceeds the 1 per cent point.

The variances obtained indicate a significant difference between varieties in average number of fruit and in average weight per fruit.

A comparison of the average yield per plant, average number of fruits per plant and the average weight per fruit of the parents and the  $F_1$  generations for the individual combinations is given in Table III.

From the data presented in Table III, it can be seen that the yield per plant of the  $F_1$  generations in the nine combinations studied is significantly higher than that of the higher yielding parent with one exception. In the cross between the Mincu and Davis Perfect varieties, the yield per plant of the  $F_1$  generation was significantly higher than that of the Mincu but did not differ significantly from that of the Davis Perfect variety.

In Table III it is interesting to note also that in all but the Davis Perfect-Mincu cross the number of fruits per plant produced by the  $F_1$  generations exceeded the number produced by either parent although not significantly so in all cases. The Davis Perfect produced slightly more fruit per plant than the  $F_1$ .

In harvesting, fruits were picked that appeared to have reached the proper size for marketing as slicers at about 6-day intervals. Since the fruits were not permitted to reach full size and weight, the data presented in Table III pertaining to the average weight per fruit probably does not indicate the true effect of heterosis on the weight per fruit in these crosses. However, it is interesting to note that the average weight per fruit in the  $F_1$  generations is significantly greater in all crosses than the average weight per fruit of the parent variety having the smaller fruit.

TABLE III—A COMPARISON OF THE AVERAGE YIELD PER PLANT, THE AVERAGE NUMBER OF FRUITS PER PLANT, AND THE AVERAGE WEIGHT PER FRUIT OF  $F_1$  PROGENIES AND THEIR PARENTS

Variety of Hybrid	Number of Plants	Yield (Pounds)		Number of Fruits		Weight per Fruit	
		Per Plant	Decrease From $F_1$	Per Plant	Decrease or Increase From $F_1$	Average	Decrease or Increase From $F_1$
Straight-8	35	6.34	-2.58**	10.8	-4.4*	0.58	-0.01
Mincu	16	5.54	-3.38**	13.3	-1.9	0.44	-0.15**
Mean of parents	—	5.94	-2.98**	12.1	-3.1*	0.51	-0.08*
Mean of $F_1$ s	69†	8.92	—	15.2	—	0.59	—
Davis Perfect	32	7.95	-0.07	14.6	+1.0	0.56	-0.03
Mincu	16	5.54	-2.48**	13.3	-0.3	0.44	-0.15**
Mean of parents	—	6.75	-1.27**	14.0	+0.4	0.50	-0.09**
Mean of $F_1$ s	68†	8.02	—	13.6	—	0.59	—
Longfellow	34	6.61	-3.46**	9.0	-6.0*	0.75	+0.07
Mincu	16	5.54	-4.53**	13.3	-1.7	0.44	-0.24**
Mean of parents	—	6.08	-3.99**	11.2	-3.8*	0.60	-0.08*
$F_1$	21	10.07	—	15.0	—	0.68	—
Early Fortune	32	8.19	-1.53**	14.6	-3.9*	0.58	+0.05
Mincu	16	5.54	-4.18**	13.3	-5.2*	0.44	-0.09*
Mean of parents	—	6.87	-2.85**	14.0	-4.5**	0.51	-0.02
Mean of $F_1$ s	49†	9.72	—	18.5	—	0.53	—
Shamrock	31	8.93	-0.79*	16.7	-0.8	0.54	-0.01
Mincu	16	5.54	-4.18**	13.3	-4.2*	0.44	-0.11**
Mean of parents	—	7.24	-2.48**	15.0	-2.5	0.49	-0.06*
Mean of $F_1$ s	55†	9.72	—	17.5	—	0.55	—
Arlington White Spine	36	7.65	-1.85**	16.0	-1.1	0.48	-0.08*
Mincu	16	5.54	-3.96**	13.3	-3.8	0.44	-0.12**
Mean of parents	—	6.60	-2.90**	14.7	-2.4	0.46	-0.10**
$F_1$	26	9.50	—	17.1	—	0.56	—
Colorado	34	7.45	-2.84**	11.7	-6.3**	0.64	+0.08*
Mincu	16	5.54	-4.55**	13.3	-4.7*	0.44	-0.12**
Mean of parents	—	6.50	-3.59**	12.5	-5.5**	0.53	-0.03
Mean of $F_1$ s	65†	10.09	—	18.0	—	0.56	—
Japanese Climbing	38	5.96	-2.93**	7.2	-7.4**	0.54	+0.23**
Mincu	16	5.54	-3.35**	13.3	-1.3	0.44	-0.17**
Mean of parents	—	5.75	-3.14**	10.3	-4.3*	0.64	+0.03
$F_1$	35	8.89	—	14.6	—	0.61	—
Improved Long Green	27	5.78	-3.36**	9.2	-7.5**	0.64	+0.09*
Mincu	16	5.54	-3.60**	13.3	-3.4	0.44	-0.11**
Mean of parents	—	5.66	-3.48**	11.3	-5.4**	0.54	-0.01
Mean of $F_1$ s	63†	9.14	—	16.7	—	0.55	—

\*Significant—at least twice the Standard error.

\*\*Highly significant—at least three times the Standard error.

†Total number of plants in two reciprocal  $F_1$ s.

As previously mentioned, the Mincu variety is much earlier than the varieties with which it is crossed. To determine whether the earliness of Mincu is expressed in the yield of the  $F_1$  generation, a comparison was made of the average yields per plant at each harvest of the parents and  $F_1$  progenies studied. A summary of this data is presented in Table IV.

TABLE IV—AVERAGE YIELDS (POUNDS) PER PLANT OF  $F_1$  PROGENIES AND THEIR PARENTS AT SIX HARVEST DATES

Hybrids and Varieties	Number	Harvests						Total
		1	2	3	4	5	6	
$F_1$ s	15	2.16	1.01	2.52	1.24	1.74	0.62	9.31
Varieties	10	0.67	1.23	1.36	1.45	1.60	0.72	7.04
Difference	—	+1.49*	-0.22	+1.16*	-0.21	+0.14	-0.10	+2.27*

\*Highly significant, at least three times the Standard Error.



The data presented in Table IV indicate that the average yield per plant of the  $F_1$  progenies was significantly higher than that of the parent varieties. Most of this difference in favor of the  $F_1$  generations was produced in the first half of the picking season. After the middle of the picking season, the difference in yield was not significant. Due to severe vine injury by heat and wind, picking was discontinued after 5 weeks. It would be interesting to note if this trend would continue over a longer picking season.

The early harvest of slicing cucumbers is more important to the growers of this region than the later harvests. In this experiment, some of the  $F_1$  generations produced a considerable quantity of marketable slicers at the first picking when the slicing parent variety produced very little or no fruit. In all crosses, the  $F_1$  generations produced much more early fruit than the corresponding parent varieties. From the data, it would appear that, by using tested parents, earlier fruits could be produced to meet the demands of the early slicing market by the use of  $F_1$  progenies.

Since  $F_1$  generations of five reciprocal crosses between the Mincu and slicing varieties of cucumbers were used in this experiment, it is interesting to compare the yields obtained when the Mincu is used as a male and as a female parent. As will be noted in Table V, no significant difference was obtained between the two reciprocal groups of crosses.

TABLE V—A COMPARISON OF THE YIELDS OBTAINED IN  $F_1$  PROGENIES OF RECIPROCAL CUCUMBER CROSSES

Crosses	Number	Mean Yield per Plant (Pounds)	Difference*
Mincu $\times$ slicing varieties	5	9.18	0.02
Slicing varieties $\times$ Mincu	5	9.16	—

\*Difference necessary for significance 0.43.

## DISCUSSION

From the data presented in this paper it is evident that the  $F_1$  generations of the cucumber crosses tested in this experiment exhibited hybrid vigor. This was expressed in increased yield per plant and in increased number of fruits per plant. The data also show that, in these crosses, in which a very early variety was crossed with later varieties, the earliness character was expressed in the  $F_1$  generations in early yields which were much larger than those of the parent varieties. There was no difference in the behavior of reciprocal crosses insofar as yield per plant of the  $F_1$  generations was concerned.

The question arises as to whether hybrid vigor produced in the  $F_1$  generations of vine crops can be utilized in practical production. The results obtained in these crosses indicate that it would appear feasible to utilize hybrid vigor in some cases in cucumbers. In general in this

region, the early-marketed slicing cucumbers bring the best prices. By using tested parent varieties and by developing a simple crossing technique, it should be possible to produce hybrid seed that would give increased early yield and possibly increased total yield at a price that would not be prohibitive.

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## Further Studies and Technic in Sweet Potato Breeding in Louisiana

By JULIAN C. MILLER, *Louisiana Agricultural Experiment Station, University, La.*

**I**N the past, little interest has been taken by the plant breeder in developing improved varieties of sweet potato. Perhaps breeding work has been neglected, especially in the continental United States, because here the sweet potato has rarely produced flowers and seed. Without the production of seed, the plant breeder's progress is handicapped and in the case of the sweet potato, he has had to depend entirely on selections of new types that have resulted from mutations. In most cases, these mutations are retrogressive.

A number of experiments were carried out in the field and in the greenhouse during 1937 and 1938 to obtain information on comparative methods of producing seed and seedling sweet potatoes.

Experiments were set up to determine the best method of overwintering the plants: (a) Plants were moved from the field to a cold frame and protected during the winter; (b) a cold frame was built around the plants in the field to protect them during cold weather; and (c) young, vigorous plants were planted in 10- to 12-inch pots and trained to a trellis in the greenhouse.

Of the three methods tested, that in which the plants were carried through the winter in pots in the greenhouse proved to be the best.

As soon as danger of frost was over in the spring, these plants were shifted to the field and trained to a wire trellis about 7 feet high. The vines were trained in a fan-shape fashion, giving each vine plenty of space for air and light. Training the vines to the trellis had a marked effect on the production of flowers. Vines of the same varieties that were left on the ground rarely flowered. The staked or trellised vines flowered about 15 days earlier and much more profusely than those left on the ground. Most of the vines that are permitted to grow on the ground do not flower at all.

After the plants had been trained to the trellis and were growing in a thrifty condition, the vines were girdled about 6 inches from the ground by cutting them about two-thirds through. Girdling also materially hastened flowering; flowering usually occurring from 30 to 45 days from the time of girdling. With some varieties that do not flower freely, all the girdled plants flowered. In some cases, it was necessary to girdle the plant several times before it could be forced into flower production.

Analyses of samples from girdled and non-girdled vines showed that the former were lower in moisture and higher in sugar and starch than the latter.

Results show that flowering and seeding habit is a varietal characteristic and that each variety has an optimum temperature and day length under which flowering and seeding occur most freely. Most varieties flower best at a day length of 12 hours in the fall, while under spring conditions, they will flower best under a 14-hour day.

Such varieties as the Porto Rico and Nancy Hall bloom best under relatively short days, while other varieties or seedlings, such as U. S. seedling No. 29879, bloom most profusely through the long days of the summer.

As a rule, a higher percentage of seed is set from crosses made in the spring than from those made in the fall. From 8 to 10 per cent of the flowers set in the fall and from 15 to 20 per cent set seed in the spring. Some varieties, such as the Creole, set 70 per cent, while in others, such as Southern Queen, not over 2 per cent of the flowers set seed during a similar period.

The time of day at which the crosses were made influenced to a great extent the percentage of seed set. The best time to make the crosses was from 8:00 to 10:00 a.m. in the fall and from 6:00 to 9:00 a.m. in the spring.

It was found that in the period from June 15 to September 15, a portion of a flowering vine could be made to take root and continue flowering within 3 or 4 days, if the vine was cut about 3 feet long and moved to a lathe house, the basal end being placed in a quart container and the vine trained to an upright string. A stock nutrient solution was made by dissolving in 1 liter of water,  $\frac{1}{4}$  pound of a complete fertilizer that analyzed 4 per cent nitrogen, 12 per cent phosphorus, and 4 per cent potash, and that had an acid base. The water in the container was changed every third day and 5 cubic centimeters of the stock solution were added.

At this season of the year, from 20 to 26 per cent of the flowers on vines growing in the solution in the lathe house set seed, while only about 5.3 per cent of the seed are set in the field.

This same method can be used late in the fall and the container can be moved to the greenhouse where uniform, warm temperatures can be maintained.

Comparative studies of the effect of weather conditions on seed setting were made. The best set of seed was obtained when pollinations were made on clear days when the mean temperature ranged from 65 to 75 degrees. Very few seed set either above or below these temperatures. During cloudy days there was very poor setting of seed. Probably a mean temperature of 70 to 75 degrees would be the most ideal temperature for flowering and setting of seed of the sweet potato.

Briefly the technic used in Louisiana is as follows: (a) The plants are carried over the winter in the greenhouse in 10- to 12-inch pots. (b) The plants are moved to the field as soon as danger of frost is past. (c) The vines are trained in a fan-shape fashion to a wire trellis about 7 feet high. The plants are spaced about 8 to 10 feet apart in the row. (d) As soon as the vines become established in the field after moving, the plants are girdled by cutting the vine about two-thirds through about 6 inches from the ground. (e) A uniform moisture supply is maintained at all times. (f) As soon as flowering occurs, crossing is done as follows: Late in the afternoon, a paper clip is placed over the tip of the flowering bud which is to open the following day, in order to hold the flower closed. Between 5:00 and 6:00 a.m. the following morning, the flowers are emasculated and the flower is again closed

by placing the paper clip over the tip. Between 8:00 and 10:00 a.m. crossings are made and the flowers tagged. The paper clip is again placed over the tip of the flower to prevent insect visitation.

When the seed capsules are about two-thirds grown, a small cloth bag is placed over them and allowed to remain until the seed is mature. The seed can be planted immediately or held in storage. At planting time, however, the seed should be treated for 20 minutes with concentrated sulphuric acid, and then washed thoroughly to remove all of the acid before planting. All of the seed treated with acid will germinate immediately; otherwise only about 50 per cent germination will result within a few days after planting and the remaining seed will germinate over a period of 3 to 4 months.

#### BREEDING PROGRAM IN LOUISIANA

The breeding program now under way in Louisiana has the following purposes in view: (a) To breed a table variety having the general characteristics of the Porto Rico variety, but more uniform in shape. This variety should have a high carotene content and a uniform flesh color throughout. (b) To breed a high-yielding variety having a higher starch content than the present varieties. (c) These seedlings are to be selected, where possible, for resistance to soil and stem rots.

Quite a number of other factors are under consideration, but those mentioned are the most important.

## Behavior of Certain Characters in Breeding Yellow Bermuda Onions<sup>1</sup>

By LESLIE R. HAWTHORN, *Texas Agricultural Experiment Station, Winter Haven, Tex.*

**F**IELDS of Yellow Bermuda onions vary greatly in any one year in the relative number of bulbs which are off-colored, split or doubled, or which have produced a premature seed stalk. These undesirable types increase the cull pile of the commercial grower and reduce his profits. In the season of 1936-37 at Winter Haven, a test was conducted with stocks of Yellow Bermuda onions in which detailed consideration was given to grades and in this the cull bulbs varied in number from 8.9 to 25.1 per cent of the crop (2). In the stock having 25.1 per cent culls, off-colors (pinks and whites) contributed 14.6 per cent. Such observations have been supported in connection with certain fertilizer experiments in cooperation with various farmers in the Winter Garden region of Texas. Since in these experiments the farmers supplied the seed, it came in most instances from different seedsmen. Following is one example of many that might be given from this unpublished data.

In the 1937-38 season two of our cooperators obtained their seed from different seedsmen, but the crop of one of these growers contained a noticeably high amount of culls compared with the other's which contained very few culls, irrespective of the fertilizer treatment. For the sake of accurate comparison, however, a record from the same fertilizer treatment is given. The first grower had 22.2 per cent and the second grower only 2.2 per cent by weight of the onions in the cull pile. The first grower was losing 100 bushels in every acre because of culls!

For the past 6 years, a program of selection and inbreeding with Yellow Bermuda onions at the Winter Garden Substation (No. 19), although necessarily conducted on a rather limited scale, indicates that by proper selection much of this off-type material could be eliminated from onion stocks. In the fall of 1932, 25 Yellow Bermuda onion bulbs all true to type were set out for seed production in 1933. All of these bulbs were taken from the remnants of an onion storage experiment conducted in the summer of 1932. In the spring of 1933 the inflorescences of a number of these plants were incased in 1-pound paper bags and seed collected from some of them. In 1934 the resulting progeny from this seed was harvested, and classified in various ways as to size of bulb, type of cull and so on. Some progenies were so good and others so poor, especially as to the amount of doubling, that selections were made both for good normal type bulbs and doubled bulbs. These were set out in the fall of 1934 for seed in 1935. In 1936 selections were again made in the same way.

In Table I are recorded the type of progeny in 1934, and the 1934 type of selection made for the seasons of 1936, and 1938, thus giving

<sup>1</sup>Approved by the Director as Paper 499 in the Technical Series of the Texas Agricultural Experiment Station.

TABLE I—NUMBERS OF NORMAL AND VARIOUS CULL BULBS FOUND IN POPULATIONS RESULTING FROM THE INBREEDING OF SUCCESSIVE GENERATIONS OF YELLOW BERMUDA ONIONS

1932	Mother Bulb Selection No.	1934				1936				1938			
		Number of Bulbs				Number of Bulbs				Number of Bulbs			
		Total	Normal	Off-color	Seeders	Doubles	Type Number	Selection	Total	Normal	Off-color	Seeders	Doubles
16		11	11	0	0	0	Normal 16-1 Normal 16-2 Normal 16-3		23	17	0	6	0
									3	2	0	1	0
									76	76	0	0	0
17		13	11	0	1	1	Normal 17-1a Normal 17-2a Double 17-2b Double 17-1b Double 18-1 Double 18-2 Double 18-3 Double 22-1b Double 22-3b Double 25-1b Double 3-1b Normal 3-2a Normal 3-3a Normal 21-2a		22	17	0	5	0
									53	40	0	13	0
									60	46	0	14	0
18		4	0	0	1	3			2	1	0	1	0
									11	6	0	5	0
									15	10	0	4	1
22		10	3	0	0	7			138	87	0	51	0
									22	15	0	6	1
25		41	17	0	0	24			136	126	0	2	8
3		46	22	0	6	18			286	246	0	40	0
									39	21	10**	7	1
									77	58	17**	2	0
21		42	23	0	0	19			43	0	0	5	1
									Died in 1937 without producing seed				
									120	116	0	2	2
									Died in 1937 without producing seed				
									Died in 1937 without producing seed				
									317	316	1*	0	0

\*\*\*Massed.

\*Developed a pink color four weeks after harvest.

\*\*All Crystal Wax bulbs.

the complete history of each of the selections which survived. More bulb selections were set out in the fall of 1932, 1934, and 1936 than are actually indicated in the table, only those which were selfed in the following spring being listed.

In 1935 and 1937 blow flies were used as pollinating agents following the method of Jones and Emsweller (4). This method has been a great aid in increasing populations. Although the first selections in 1934 were made primarily for doubling and non-doubling, other characters such as premature seeding and off-colors made their appearance in the various populations from time to time. Thus we have a record for three generations of all of these characters which appeared in this program of inbreeding. Before discussing this record, a brief statement concerning the effect of weather on some of these characters is necessary.

#### EFFECT OF WEATHER

Observations by Magruder and Hawthorn on 20 varieties of onions in 1933 indicated that sudden severe freezing caused onions to double badly, but not necessarily to seed prematurely (5). These observations have been supported by the writer in connection with other experimental work previously reported (1) so far as Yellow Bermuda onions are concerned. Also in seasons having prolonged periods of sub-normal temperatures, but not necessarily below freezing, Yellow Bermuda onions are likely to produce large numbers of premature seed stalks (3). Such onions are classified as seeders at harvest time. So far as this inbreeding experiment is concerned, 1934 was favorable for doubling, and the weather of 1936 and of 1937-38 to a lesser extent favored premature seeding.

#### DOUBLES

All the original mother bulbs planted in 1932 lacked any sign of doubling, but in 1934 all but the progeny of bulb No. 16 had doubles (Table I). Only No. 17 approached No. 16 in freedom from doubles, it having only one doubled bulb out of a total of 13. On a percentage basis the other progenies ranged from 39 to 75 per cent doubles. Selections were made in Nos. 16 and 17 as well as Nos. 3 and 21 for normal true-to-type bulbs, and in Nos. 3, 18, 22 and 25 for doubles.

In 1936 doubles were remarkably low in number in those populations in which they appeared. Although on casual observation it may appear that the selection for doubling and non-doubling had little effect, nevertheless the appearance of doubling in 1936, though there were very few doubles, does seem to be related to the type of population from which the doubled onions came in 1934. None of the selections from the progenies of bulbs 16 and 17 had doubles in 1936, and in 1934 there had been only one doubled bulb in their combined populations. In contrast to this, one selection in line No. 3 (3-2a), one in 18 (18-3), one in 21 (21-2a), one in 22 (22-3b), and one in 25 (25-1b) had one or more double bulbs in their populations (Table I). These lines in 1934 all had a high number of doubles.

From the point of view of having a continuous record on all types of selections the year 1938 was an unfortunate one for practically the



only selections to survive until that season were those tracing back to bulb No. 16 and all of these without exception completely lacked doubled bulbs in 1938. As a check against these only the progeny of selection 22-1b-1c remained. All the other lines in which it was planned to make selections in the fall of 1936, either failed to survive the 1936 summer storage period or died before producing seed in 1937.

Selection 22-1b-1c had two doubled bulbs out of a total of 120, and traced back to bulb No. 22 which in 1934 had seven out of 10 doubled bulbs. It is believed that had more of the lines selected for doubling lived through to 1938 they would have again contained at least some doubles in contrast to the complete absence of this character in the 16-3 selections. Not only does the record of selection 22-1b-1c suggest this, but observations made in cooperative fertilizer tests in the 1937-38 season indicated that few, if any, commercial strains of Yellow Bermuda onions were free of seeders, doubles and off-colors in that year. Although no separate record on doubles is available, the writer saw doubled onions in each of the cull piles from which the percentage of culls by weight was calculated. In the same fertilizer treatment these amounted to: 2.2, 8.7 and 22.2 per cent for three lots of onions coming from different sources. In another field having a different fertilizer treatment culls amounted to 27.8 per cent by weight and many of these were doubles.

Thus the complete lack of doubles in a total of 420 bulbs (317 of which were in one massed lot) representing seven sub-lines of No. 16-3 is considered significant. These figures together with the others on doubling in Table 1 suggest the fact that selection for freedom from this defect can be made with favorable results.

#### PREMATURE SEEDERS

As in the case of doubles, all the original mother bulbs planted in 1932 lacked any sign of being seeders. Only three out of seven lines had seeders in 1934 and the numbers of such bulbs were comparatively small, but in 1936 every one of the selections made in 1934, except one, had seeders in its progeny, and not one selection for seeding had been made (Table I). In most cases the numbers of seeders were comparatively high. As previously explained, the weather conditions were undoubtedly favorable for premature seeding. In 1936 several selections for seeding were made and one was carried through to 1938. Weather conditions in the 1937-38 season were fairly favorable to seeding, and the bulb (22-1b-1c) selected for seeding had seeders in its progeny in 1938. A number of normal bulbs were chosen in 1936 from 16-3, the only line having no seeders in 1936. Some of these were selfed and a number were massed under one large cage in which thousands of flies were liberated. Of the lots which survived until 1938, not one of the 420 bulbs selected had a seeder.

The loss of material, especially of lines which were doubling and seeding, was again unfortunate so far as an examination of the 1938 data for seeding is concerned. Much of that which has been stated about doubling also applies here. Seeders were very common in 1938. They were so abundant in the Station's fields and in other onion

breeding material that the lack of them in the No. 16-3 selections was very conspicuous. The cull piles of the fields in the cooperative fertilizer tests mentioned in the discussion on doubling all had their share of seeders. This seems to indicate that selection can affect the amount of bolting within the variety.

#### OFF-COLORS

No selections were made in this inbreeding program for any color but that of a normal Yellow Bermuda, and the data in Table I would indicate that the Yellow Bermuda bulbs chosen originally in 1932 were on the whole very free from hidden color defects. In 1936 a number of Crystal Wax bulbs showed up in second generation lines 3-2a and 3-3a. If color alone is considered it will be noted that in both these instances there is a close approximation to a 3:1 ratio. Line 3-2a had 29 normal to 10 off-color, and 3-3a had 60 to 17. Considering these as one population the ratio becomes 89 to 27. Using the chi square formula to determine the significance of this as a possible 3 to 1 ratio, the calculation gives a value of 0.184 for chi square, and the chance of the ratio representing a 3 to 1 one is 7 to 3, which is highly significant. This simple Mendelian ratio suggests that perhaps the colors of yellow and white in Bermuda onions are simple allelomorphs. Perhaps during the preliminary work of the first year some Crystal Wax pollen was allowed to reach some of the flowers on bulb No. 3.

In spite of this rather noticeable exception to the very uniform color seen in all the populations grown in this project, it would appear that populations of Yellow Bermuda onions resulting from an inbreeding program are not likely to have many (if any) off-colored bulbs in them. The writer has yet to see a commercial field of Yellow Bermuda onions which entirely lacks pink as well as Crystal Wax bulbs. Thus the absence of off-colors in most of the populations of onions now under discussion is of more than passing interest. Under commercial conditions one Crystal Wax bulb allowed to seed in a field of Yellow Bermuda onions, probably contaminates many of the Yellow Bermuda bulbs around it, and accounts for some at least of the Crystal Wax bulbs seen in commercial fields. Others may be due to seed mixing.

Pink bulbs were extremely rare too. None were ever actually observed at the time of harvest. An occasional bulb having a slight tinge of pink was seen in some populations during the summer storage period, and such bulbs were never planted in the fall. The one off-color bulb found in the massed lot of 16-3 in 1938 was really of this type.

#### STERILITY AND REDUCED VIGOR

No data are available on these factors. From general observation, however, it appears that complete sterility of a plant is rather rare. General observation indicates that inbreeding reduces the vigor of the Yellow Bermuda plants. Tops are likely to be shorter and the bulbs smaller. The plants are also less likely to withstand adverse conditions, such as disease, and insect pests. The lack of data in 1938 is in part due to loss of seed plants in 1936-37, and in practically every case the

plants which died were never at any time very vigorous. Line 18-3-1 was especially weak, and in its failure to produce seed, we lost a line which traced back to a mother bulb having nothing but seeders and doubles in the first generation (Table I). Incidentally lines 22-3b-1 and 25-1b-1c, both of which had many doubles in the first generation also died seedless in 1937.

#### LINE No. 16-3

As one tangible result of this inbreeding program we collected in 1937 seed from five selfed plants, and this seed planted in the fall of 1937 did not produce any off-colored, bolting, or doubled onion in 1938 (Table I). A massed lot from the same source resulted in only one off-type onion, a bulb which at harvest time was not pink, but which became so 4 weeks later. This line has apparently lost size, but genetically it must be very homozygous for factors responsible for normal bulbs.

#### SUMMARY

This paper reports some observations made in the course of an inbreeding program with Yellow Bermuda onions in which selections for normal bulbs, as well as for doubles and seeders, were made. The data indicate that: (a) inbreeding combined with selection away from the undesirable characters of doubling, and premature seeding (bolting) can result in lines of onions free from these characteristics. (b) The bulb colors, yellow and white, may be simple allelomorphs. (c) As a result of the specific program described, the Station has one line of Yellow Bermuda onions which genetically seems very homozygous and is considered to be superior to commercial strains in its freedom from the defects of doubling, seeding, and off-colors.

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## Tomato Importations for Breeding

By H. F. BUTLER, *University of Tennessee, Knoxville, Tenn.*

THE first step in any breeding project is to find suitable parents that have the qualities and characteristics desired. Southern tomato breeding for the climatic belt represented by Tennessee requires tomatoes of commercial quality, resistant to wilt and free from defoliation. All commercial varieties tested to date show a high percentage of defoliation soon after the fruit starts to mature. A host of tomato troubles follow this loss of foliage. *Septoria*, *Alternaria*, and *Cladysporium* are diseases involved. Perhaps high soil temperatures, which are common in the South, are an important factor. Various fertilizer treatments have failed to reduce appreciably the loss of leaves. Our search for suitable parents was extended to include importations from various parts of the world, which we secured through the cooperation of the Bureau of Plant Exploration and Introduction.

Two hundred and eighty-two different foreign tomatoes have been secured and tested. Of this number, 265 were on trial during the summer of 1938. A complete set of notes was taken about August 15, and another about September 15. The notes taken covered plant characters, fruit characters, and extent of defoliation. Thirty-three importations failed to develop fruit under field conditions. All promising plants were staked, and the best were selected for further observation. Of the plants tested during the summer of 1938, five were finally selected as worthy of a place in next year's plantation.

The tomatoes came from 12 different countries: two from Asia, one from Africa, and several from South and Central America. Of the desirable varieties, 80 per cent came from Peru and from about half of the importations. The tomato varieties, or strains, that have been selected as parents showed little defoliation during last summer, when conditions were conducive to the development of leaf diseases. Some of the strains from Peru show lack of ability to set fruit under field conditions in Tennessee. One desirable plant came from Argentina. The fruit was medium in size, excellent in quality, free from cracking, and very smooth and solid. This strain produced fruit until it was killed by frost. The defoliation was higher in these plants than in varieties from Peru, but was not severe enough to cause the plant to stop fruiting.

There is little correlation between the type of plant and the country from which it came. Two exceptions to this rule have been observed. Most of the tomatoes from Argentina produce fruit of commercial size and plants of the usual commercial type; plants from Peru are spreading or sprawling, with very few of the commercial type or with fruit of commercial size. All strains of the hairy, leather-leaf type came from Peru, and many of these failed to fruit under field conditions.

Following are descriptions of varieties received from the different countries.

*Peru*.—The importations from Peru, as a whole, were badly defoliated. Four selections, however, were almost free from leaf spots and

TABLE I—DEFOLIATION OF IMPORTED TOMATOES AUGUST 15, 1938

Importations From	Under 20 (Per Cent)	20 to 39 (Per Cent)	40 to 59 (Per Cent)	60 to 79 (Per Cent)	80 and Over (Per Cent)	Number of Importations
Peru .....	5.3	7.7	16.3	63.0	7.7	199
Argentina .....	None	None	78.9	21.1	None	19
Bolivia .....	None	3.3	55.0	41.7	None	60
Brazil, Chile, and Venezuela .....	None	None	23.5	73.5	3.0	34
Central America and Mexico .....	None	None	20.0	60.0	20.0	5
Asia .....	None	None	36.4	63.6	None	11
Morocco .....	None	None	None	71.0	29.0	7

TABLE II—GROWTH HABITS OF IMPORTED TOMATOES

Importations From	Erect (Per Cent)	Semi-Erect (Per Cent)	Semi-Erect, Spreading (Per Cent)	Sprawling (Per Cent)
Peru .....	0.8	34.1	44.9	20.2
Argentina .....	5.3	42.1	52.6	None
Bolivia .....	6.6	35.0	58.4	None
Brazil, Chile, and Venezuela .....	None	32.3	64.7	3.0
Central America and Mexico .....	None	None	100.0	None
Asia .....	None	45.4	54.6	None
Morocco .....	None	None	86.0	14.0

TABLE III—SHAPE OF IMPORTED TOMATOES

Importations From	Globe (Per Cent)	Oblate (Per Cent)	Flattened (Per Cent)	Pear Shape (Per Cent)	Plum Shape (Per Cent)	Cherry Shape (Per Cent)
Peru* .....	3.9	3.9	24.0	1.6	17.8	24.0
Argentina .....	52.6	5.3	10.5	5.3	21.1	5.3
Bolivia† .....	8.3	15.0	38.3	8.3	26.6	1.7
Brazil, Chile, and Venezuela .....	23.5	8.8	23.5	8.8	26.5	8.8
Central America and Mexico .....	None	20.0	40.0	None	20.0	20.0
Asia .....	18.2	27.3	27.3	None	27.3	None
Morocco .....	57.0	29.0	None	14.0	None	None

\*32 plants did not set fruit.

†One plant did not set fruit.

TABLE IV—SIZE OF IMPORTED TOMATOES

Importations From	Under 1 Inch (Per Cent)	1 to 1 7/16 Inches (Per Cent)	1 1/4 to 1 15/16 Inches (Per Cent)	2 to 2 7/16 Inches (Per Cent)	2 1/2 to 2 15/16 Inches (Per Cent)	3 Inches and Over (Per Cent)
Peru* .....	24.8	18.6	16.2	10.1	3.1	None
Argentina .....	None	21.1	21.1	36.9	15.8	5.3
Bolivia† .....	1.7	33.2	24.9	24.9	11.9	1.7
Brazil, Chile, and Venezuela .....	14.7	29.4	3.0	35.3	14.6	3.0
Central America and Mexico .....	40.0	None	20.0	40.0	None	None
Asia .....	9.1	18.2	36.4	None	36.4	None
Morocco .....	None	14.5	14.5	71.0	None	None

\*35 plants did not have mature fruit.

†One plant did not mature fruit.

other diseases. One of these selections showed no leaf spots and only 3 per cent defoliation by August. Another selection was destroyed by wilt. The strains from Peru were semi-erect to sprawling in habit of growth, and produced fruits that were small and undesirable in shape. There were 32 lots that did not set fruit, while others failed to mature. The tomatoes from Peru were of several different species; namely *Lycopersicum esculentum*, *L. humboldtii*, *L. peruvianum*, and some the species of which have not yet been determined. All four of the strains selected as parents are from lots whose species have not been determined. Three of these P.I. numbers are 126936, 127826, and 127827B. These selections are large, semi-erect-spreading, with dense foliage; the leaves are large and thick; the stems and leaves have a heavy pubescence and a strong offensive odor, and attract a large number of hornworms. The other selection, P.I. 127827A, is sprawling, leaves small, size of plant small, and very healthy.

*Argentina*.—Most of the varieties from Argentina were badly defoliated, but in habits of growth, size and shape of fruits, were very desirable. One strain that was selected as a parent, P.I. 128285, produced excellent fruit, which was of medium size, globe-shaped, free from cracks, and remained in good condition for a long time after ripening. This importation was of the *Lycopersicum esculentum* species. The plant was very similar to our leading commercial varieties, having dense foliage and only a small percentage of defoliation.

*Bolivia*.—The tomatoes from Bolivia were about average in defoliation, and erect to semi-erect-spreading in habits of growth. The fruits were undesirable in shape; and several of them, while of large size, were furrowed and flat. No selections were saved from this group, and all were of the *Lycopersicum esculentum* species.

*Brazil, Chile, and Venezuela*.—No importations from Brazil, Chile, or Venezuela proved promising as parents. Nearly all plants showed bad defoliation, caused mostly by *Septoria* leaf spot. All strains were semi-erect to sprawling in habits of growth. The fruits varied in size and shape, many being very undesirable. All lots were of the *Lycopersicum esculentum* species except four, of which the species have not been determined.

*Central America and Mexico*.—The strains of tomatoes from Central America and Mexico were badly defoliated. The leaves were slight to medium in size; the fruit was red, and varied in size and shape. All varieties were of *Lycopersicum esculentum* species, but were not desirable for parents.

*Asia*.—Notes on tomatoes from Asia rate them as low because of severe defoliation. None were selected as parents, although all were of the usual commercial type and of *Lycopersicum esculentum* species. The foliage was medium to dense; all fruits were red, except those of one lot from Afghanistan, which were yellow.

*Morocco*.—Tomatoes from Morocco had sprawling habits of growth, and rather large, red fruit of desirable shape. All lots were *Lycopersicum esculentum*. None were selected for parents. All of these plants in the trial plots defoliated badly.

## Yield Studies as Related to Asparagus Breeding

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**I**N the improvement of the asparagus plant, yield is a primary consideration. This is especially true where a breeding program is involved, and desirable parents are to be selected. Records taken at the California Station indicate that the yield of a plant may be relatively high one year and low the next. Just how long yield records should be taken before the yielding ability of a plant is established, is a question about which there is some disagreement among investigators in this field.

An attempt to establish improved strains of asparagus was started at this Station in 1929. One hundred and fifty-nine plants were selected from a 400-acre field of 2-year-old Mary Washington plants on the basis of yield, color, smoothness, tightness of head, cross section, tenderness, and flavor. The selected plants were considered to be outstanding for three or more of these characters but none were outstanding in all of them. The plants were removed with as much of the root system as feasible and replanted at Davis in 1929. One hundred and thirty-nine of these plants survived transplanting. They were not cut until the 1932 season and then for only 4 weeks. Subsequently they were harvested for the entire season which usually ends about May 15th at Davis. The yields of these plants are presented in Fig. 1 along with five male plants that have been used as parents in breeding.

Prior to transplanting the plants mentioned above, a number of crosses were made among several of these plants. After a rigorous selection of the progenies, 350 plants were selected and planted. The rating of the highest yielding 25 plants at the end of 4 years is compared with their rating for each of the 4 years. A study of Table I will reveal that there is considerable fluctuation in the rating of these plants. The data shows in the years 1934 to 1937 that plants 11, 16, 19, and 18, respectively, were among the highest 25 plants on the basis of total yield for the 4 years, and that with only a few exceptions all were among the highest 10 per cent after 1934. So in

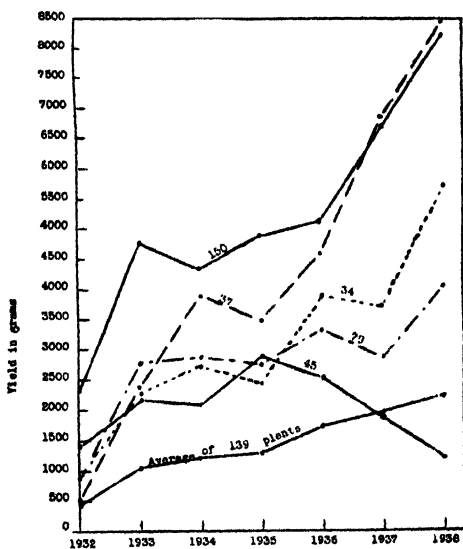


FIG. 1. Yields of five male plants used as parents in breeding work (Yield expressed in grams).

general early yielding plants are frequently high yielding at the end of 4 years. The total yields for plants 3 and 4 are 5,644 and 5,412 grams respectively. It is obvious that the yields the first 2 years on plant 3 were relatively more important than those of the last 2 years in rating this plant, while the reverse is true for plant 4. Plant 19, considered to be the best plant in all characters in the entire plot has a very low rating the first 2 years and very high the last 2 years. What is the future trend of these plants? Can the future yield trends be predicted on the basis of 4 years records?

Further information on this point can be obtained by examining the five individual male plant yields presented in Fig. 1. These yields are for 7 years and are compared with the average of the plot. The fluctuating yield trend is graphically illustrated here and is more or less typical of all the plants in the plot as well as in subsequent plantings, although the latter have not been harvested as long. The yields of these particular males are shown because they have been used more often in breeding work than any of the others.

As a starting point in the breeding program it was assumed that plants which gave a high yield the first year would continue to be high yielding throughout their life and low yielders would always be low yielders. In general this has been found to be true at this Station (Table I) and by other investigators as Currence and Richardson (1) and Robb (2). A study of Fig. 1. and Table I will reveal the error of applying such generalities to all individual plants. The plants in Fig. 1 fall into three classes: plants 37 and 150 exhibit a pronounced increase in yielding ability as they grow older; plants 34 and 79 exhibit only a slight increase in their yields in later years, and plant 45 has distinctly decreased in yield.

TABLE I.—RATINGS OF ASPARAGUS PLANTS ARRANGED ACCORDING TO GREATEST YIELD, 25 OF THE HIGHEST YIELDING PLANTS OUT OF 350 PLANTS GIVEN (PLANTS SPACED 3 FEET APART IN ROWS 8 FEET APART)

Year Harvested	Annual Rating Based on Yields														
1934	8	350*	1	19	9	3	4	33	38	28	12	34	10		
1935	5	1	2	23	15	11	18	10	3	14	8	13	4		
1936	4	2	8	1	3	20	10	47	22	11	21	36	26		
1937	1	2	10	4	8	22	23	3	25	18	15	7	52		
Rating based on total yield of 4 years	1	2	3	4	5	6	7	8	9	10	11	12	13		

Year Harvested	Annual Rating Based on Yields														
1934	23	27	113	13	14	143	134	63	47	52	40	61			
1935	24	30	35	16	7	119	17	29	31	178	46	44			
1936	16	19	9	18	50	6	17	14	12	7	34	27			
1937	17	12	11	38	32	5	33	27	33	6	19	31			
Rating based on total yield of 4 years	14	15	16	17	18	19	20	21	22	23	24	25			

\*No yield on this plant.

Due to their early high yields plants 45 and 150 were used as male parents in breeding work in 1932. Although plant 150 out-yielded plant 45, the latter was considered the best plant all points considered. In fact, the only point which this plant lacked, to be considered perfect



from a breeding viewpoint, was the heads of the spears were not as tight as desired. Subsequent records show that this plant failed to respond as expected, although it would have been considered a very good plant at the end of 4 years. Furthermore, the progeny of crosses and backcrosses of this plant indicate that a considerable percentage will also be short-lived. More data are needed to determine this point, although several of the progeny are already dead.

Just how long plant records should be taken before a fairly definite yield trend of a plant can be determined under California conditions remains a problem, but if time and facilities permit, records should be taken for at least 7 or 8 years to avoid using short-lived plants as parents. To be sure, it is not known yet whether a long or short life span is an inheritable character in asparagus, only a progeny test of this character or any others can determine the breeding merits of such a heterozygous plant as asparagus.

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# Effect of Certain Storage Treatments on Field and Laboratory Germination of Seeds of Imperial 152 and Imperial 615 Lettuce

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**M**ANY inherent and environmental factors have been shown to influence lettuce seed germination, such as age of seed, variety, individual plant, physiological age of plant at time of seed harvest, fertilization of mother plant, light, temperature, carbon dioxide, and oxygen (1, 2, 3, 5, 6, 7). Recently, stimulation of germination has been secured by weak concentrations of certain chemicals used as germination media (4).

The practical importance of one or more of these conditions has been shown in Arizona, where difficulty may be experienced in securing desirable stands from seed harvested the current year. Seed normally matures in the Salt River Valley during May. Plantings of the fall crop are made during relatively high temperatures of September. In connection with seed selection and multiplication within the varieties 152 and 615, or with material used for breeding purposes, it may be necessary to plant the seed less than 4 months after time of harvest. Particularly in the case of individual plant selections is the problem of inducing germination important, because of the fact that seeds from certain plants exhibit such profound dormancy that stands secured are very poor. In lots composed of seeds from a number of plants, stands can be expected to be better. The usual commercial practice, among large growers, is to store freshly harvested seed in places of high temperature (range of 80 to 120 degrees F) for 4 to 5 months following harvest. This seed then produces favorable stands of plants under field conditions with no increase of seeding rate required.

This particular problem appears to be one of dormancy exhibited by "new" seed, an age factor. The development of some simple means of seed storage or seed treatment which would result in higher germination of these seeds is important. Of still greater value would be the development of a treatment which would materially aid in securing stands of early fall plantings without the frequent irrigations necessary for evaporative cooling of the soil.

The storage treatments discussed in the present report were begun to determine the effect of storage temperature and humidity on germination of seed, and, ultimately to study their effect on seedling vigor. Unexplained variations in seedling vigor and mortality sometimes present in commercial plantings may, in part, be influenced by seed storage environment.

## MATERIALS AND METHODS

Seed of Imperial 152 and Imperial 615 were harvested May 20, 1938. The seeds were taken to the laboratory, cleaned, and kept at room temperature until placed under the various storage conditions on

June 28. The laboratory was dry air cooled and the temperature range was 75 to 88 degrees F.

At the time seeds were placed under the various storage conditions, moisture determinations made at 100 degrees C for 48 hours showed a water content of 4.9 per cent for Imperial 152, and 5.3 per cent for Imperial 615. This indicates that under the low humidity conditions of the Salt River Valley, air dry seeds may be relatively low in moisture content.

The following storage temperatures were used: (a) Seed stored in a ventilated temperature recording box on the Mesa Experimental Farm. Up to November 5, the lowest temperature which had been recorded was 38, and the highest 112. These seeds were therefore exposed to rather wide fluctuations in temperature, and it is intended to leave them throughout the year under these outside conditions. (b) Seed stored in an air cooled and heated building, with temperature ranges up to November 5 of 75 to 88 degrees F. (c) Seed stored at 105 degrees F. in an electric oven, with accurate temperature control. (d) Seed stored in a cold storage vault with temperature of 40 degrees F. (e) Seed stored in the open, in an inverted glass container, screened at the bottom, until September 27, when they were moved into the shelter described in (a). These seeds were without doubt exposed to daytime temperatures considerably higher than the maximum of 112 recorded by the thermograph in the shaded temperature box. In late July a rainstorm caused considerable wetting of seeds of 152 at the bottom of the inverted container. Although these moist seeds were removed, considerable increase in humidity no doubt occurred throughout the container.

At each storage temperature, seeds were placed in muslin bags and small, air tight glass bottles. In addition, at three temperatures, seeds were placed over sulphuric acid made up to concentrations necessary to provide certain humidities. The various treatments are shown in Table II.

Laboratory germinations were made in darkness in petri dishes. A single Whatman No. 2, 9.0 centimeters, filter paper was placed in the bottom of the dish, the dry seeds counted into marked areas on the paper, 3.5 cubic centimeters of water added, and the dishes imme-

TABLE I—GERMINATION OF LETTUCE SEED, IMPERIAL 152 AND 615, TEMPERATURE, 77 DEGREES F, JUNE 24, 1938

Seed Description	Per Cent Germination			
	40 Hours		72 Hours	
	Variety 152	Variety 615	Variety 152	Variety 615
Two years old, stored at 40 degrees F and 50 per cent humidity, first harvest*	95	—	95	—
Two years old, stored at 40 degrees F and 50 per cent humidity, fourth harvest**	82	—	82	—
New seed, 35 days after harvest†	3	4	4	17

\*First seeds harvested from plants, 1936 seed, 2 years old.

\*\*Fourth seed harvest from plants, 1936 seed, 2 years old.

†Seed of these strains used for storage treatments.

diately placed in the dark. For the 24-hour germination counts, the petri dishes were removed from the small closed box in which they had been placed, and exposed to diffuse light for approximately five minutes, while counts were made. Quadruplicate lots of 20 or 25 seeds each were used for each of the treatments.

Under field conditions, quadruplicate lots of 100 seeds each were planted for each of the treatments. Four blocks (or rows) were provided, with the 36 treatments planted at random in each block. Seeds were covered by hand. In neither of the field germination lots did rain occur from time of planting until complete germination data were secured.

TABLE II—LETTUCE SEED GERMINATION, LABORATORY GERMINATION, 1938  
SEED HARVESTED MAY 20, PLACED IN STORAGE TREATMENTS JUNE 28,  
WITH EXCEPTION OF LOTS (B) AND (C)

Temperature Degrees F	Relative Humidity	Container	Per Cent Germination									
			August 17		August 22				October 24			
			74 De- grees F		80 Degrees F				77 Degrees F			
			72 Hours		24 Hours		72 Hours		24 Hours		72 Hours	
			152	615	152	615	152	615	152	615	152	615
38-112 (c)	—	Muslin bag	94	98	32	40	85	94	92	89	97	92
38-112 (c)	—	Glass, air tight	89	96	8	9	65	83	93	82	99	98
38-112 (c)	—	Inverted, sun, open	88	84	6	0	71	35	12	78	59	91
75-88 (d)	—	Muslin bag	100	94	55	45	93	91	93	92	94	96
75-88 (d)	—	Glass, air tight	96	95	38	48	80	86	86	92	92	97
75-88 (d)	10	Open over acid	64	81	0	0	3	4	0	0	13	13
75-88 (d)	50	Open over acid	99	95	35	36	70	91	92	85	96	95
75-88 (d)	75	Open over acid	48	78	1	1	10	28	1	1	29	52
105	—	Muslin bag	98	98	14	10	73	70	77	77	92	97
105	—	Glass, air tight	96	96	31	15	91	89	91	88	92	94
105	50	Open over acid	21	63	0	0	3	1	0	0	0	0
105	75	Open over acid	53	66	0	1	1	16	0	1	37	70
40	—	Muslin bag	95	98	13	15	50	74	81	87	91	94
40 (a)	—	Glass, air tight	51	81	0	0	8	30	79	2	95	59
40	10	Open over acid	86	83	9	13	53	75	81	84	90	95
40	50	Open over acid	90	94	14	20	50	88	91	92	97	97
40	75	Open over acid	54	60	0	0	0	6	6	1	72	78
40 (b)	50	Open over acid	96	—	80	—	95	—	94	—	94	—
40 (c)	50	Open over acid	80	—	71	—	81	—	59	—	74	—
Difference required for significance			8.60		6.48		8.05		3.32		5.96	
F value found			4.92		10.95		18.95		14.92		37.69	
F value required at 1 per cent level			1.39		1.39		1.39		1.39		1.39	

(a) After August 22, seed of 152 left exposed in this lot. (b) First seed harvest from plants, 1936-seed 2 years old. (c) Fourth seed harvest from plants, 1936-seed 2 years old. (d) Stored outside under shade. (e) Controlled room temperature.

Seed used in the present storage tests originated from single plant selections for Imperial 152 and Imperial 615 in 1935. Seeds of the two plant selections were multiplied, until in 1938 sufficient seeds were available for storage work.

## RESULTS

*Laboratory Germination.*—The pronounced dormancy of the seed, using a germination temperature of 77 degrees F, just previous to be-

TABLE III—LETTUCE SEED GERMINATION, FIELD GERMINATION, MESA EXPERIMENTAL FARM, 1938, SEED HARVESTED MAY 20, PLACED IN STORAGE JUNE 28, WITH EXCEPTION OF LOTS (B) AND (C)

Storage Conditions			Per Cent Germination							
Temperature Degrees F	Relative Humidity	Container	September 27 Irrigation				November 5 Irrigation			
			October 4 Count		October 13 Count		November 15 Count		December 1 Count	
			152	615	152	615	152	615	152	615
38-112...	—	Muslin bag	48	68	51	74	65	63	82	84
38-112.....	—	Glass, air tight	45	56	55	61	66	66	75	86
38-112.....	—	Inverted—ex- posed to sun	36	52	44	66	31	58	51	77
75-88 .....	—	Muslin bag	66	89	75	90	70	71	81	80
75-88 .....	—	Glass, air tight	65	68	74	70	71	61	84	82
75-88 .....	10	Open over acid	2	4	12	26	8	18	44	63
75-88 .....	50	Open over acid	45	81	54	86	67	53	80	79
75-88 .....	75	Open over acid	10	26	27	43	52	39	76	70
105.....	—	Muslin bag	67	80	75	85	59	59	67	68
105.....	—	Glass, air tight	66	71	68	76	57	64	73	79
105.....	50	Open over acid	2	2	7	11	0	0	19	7
105.....	75	Open over acid	7	22	28	50	43	51	64	72
40.....	—	Muslin bag	21	28	29	46	64	67	74	77
40 (a).....	—	Glass, air tight	5	5	17	21	51	36	74	63
40.....	10	Open over acid	11	24	19	54	65	65	80	81
40.....	50	Open over acid	23	40	28	63	71	62	81	75
40.....	75	Open over acid	3	8	11	16	43	64	67	18
40 (b).....	50	Open over acid	70	—	68	—	72	—	82	—
40 (c).....	50	Open over acid	49	—	48	—	35	—	47	—
Difference required for significance .....			5.21		5.66		5.79		3.77	
F value found .....			25.61		19.21		11.77		21.38	
F value required at 1 per cent level .....			1.39		1.39		1.39		1.39	

(a) After August 22, seed of Imperial 152 left exposed. (b) First seed harvest from plants, 1936, seed 2 years old. (c) Fourth seed harvest from plants, 1936, seed 2 years old.

ginning the storage treatments, is shown in Table I. Seeds of Imperial 152, 2 years old, stored at 40 degrees F, and 50 per cent humidity have been used for comparative purposes, and are included in all of the germination tests. Laboratory germination tests on August 17, August 22, and October 24, are shown for all treatments in Table II.

On August 17, at a temperature of 74 degrees F, relatively high germination percentages were found for most lots. There were, however, several significant differences in germination. The difference between any two comparisons, either for varieties or treatments, necessary for significance is shown in the Table. Analysis of variance was used in analyzing the data.

Germination of seeds stored in muslin bags or air tight containers was good under all temperature storage conditions, with the exception of the air tight storage at 40 degrees F. Imperial 152 seed gave especially low germination when stored air tight at this temperature.

At 75 to 88 degrees F storage, seed germination was excellent at 50 per cent humidity, but poorer at 10 and 75 per cent humidity. After 105 degrees F storage, at humidities of 50 and 75, germination was relatively low. After 40 degrees F storage, germination was lower for seed stored under 75 per cent humidity than at 10 and 50.

Another test was made August 22 to determine germination behavior of the various lots at a higher temperature, 80 degrees F. Data

are presented for percentage germination at 24 and 72 hours. It is especially interesting to note that "72-hour" germination of seed stored at high temperatures, either open or air tight, was in general much better than for those stored at 40 degrees F. Seed of Imperial 152 kept at the 40 degrees F storage again gave lower germination than seed of Imperial 615. Since germination of seed kept stored air tight at 40 degrees F was obviously low, it was decided to leave the lot of Imperial 152 open after the August 22 sampling.

Significantly high germination of 2-year-old seed, after 24 hours, indicates that, even for the highest germinating lots, "new" seed showed dormancy effects. After 72 hours, percentage germination of the 2-year-old seed was no better than for some of the "new" lots.

For outside and room temperature storage, germination of seed from closed containers was significantly lower than for the open (muslin bag) stored seed. After storage at a temperature of 105 degrees F, germination of open stored seed was definitely lower than for air tight storage.

Some of the differences between treatments in the germination data for 80 degrees F, are not apparent in the 74 degrees F data, as, for example, the comparative germination of open and sealed seed stored at 105 degrees F.

A further test on October 24, at 77 degrees F, showed good germination of all lots, with the exception of certain of the humidity treatments, and Imperial 615 at 40 degrees F, stored sealed. The Imperial 152 lot which had been sealed until August 22, then left open, gave significantly higher germination than the sealed Imperial 615 lot. The difference was very pronounced for the 24-hour germination count.

We have not stressed, nor can we explain, the wide differences associated with the effect of various storage humidities. The sulphuric acid used was placed in the bottom of square,  $\frac{1}{2}$  gallon glass jars. Soldered copper wire baskets, with glass legs, were made to fit into the jars, so that acid would come in contact only with the glass legs. Small glass bottles, holding about 50 grams of seed, were then placed in copper baskets. The jars were covered with ground glass lids, so that the containers were air tight. We do not know whether the noted significant differences in data are due to the sealed storage, to humidity, to respiration products, or to the effect of volatile products from possibly impure acid. Whatever the causal factor, it will be shown in field data for late planted seed, that the depressing effects were largely temporary in nature, and that the embryos were not killed.

*Field Germination:*—Field plantings, in a dry clay loam soil, were made at uniform depths ( $\frac{1}{4}$  inch) September 27 and November 5. The plots were irrigated on the same days. Records of the number of plants appearing above ground were obtained on two dates for each of the plantings. Relatively low soil temperatures slowed down germination for the November 5 planting, so that dates of counts were considerably later, after time of planting, than for the September 27 seedling. Data are presented in Table III.

For the October 4 seedling count, germination of open or sealed

lots of seed was far better from high temperature storage than for 40 degrees F storage. In every case sealed lots of Imperial 615 gave significantly lower germination counts than open lots.

It is generally assumed that, because of heavy seeding for western planted lettuce, germination of 50 per cent of the seed will give satisfactory stands. Relatively heavy stands are required, before the thinning operation, because of seedling mortality due to many factors. Therefore, under the conditions of this experiment, high temperature storage may be considered as giving satisfactory stands, while the 40 degrees F storage gave relatively unsatisfactory stands. We refer to the open and sealed storage lots. The Imperial 615 lots stored at 40 degrees F, with 10 and 50 per cent humidity, gave satisfactory stands.

For the October 13 count, germination of seeds of Imperial 615 was significantly higher than for Imperial 152, in 13 out of the 17 comparisons. For the other four, differences were not significant. Under these conditions, seed of Imperial 152 exhibited a more profound dormancy. We have used dormancy in this paper as referring to any delay or significant differences exhibited between comparative germination percentages of various seed lots.

In general, those lots which had germinated well by October 4 did not show as high increase in percentage germination during the following 9 days as those lots which showed low germination for the first count. The 2-year-old seed actually showed slight decreases, due to plant mortality. "New" seed, stored at high temperatures, in general gave as high, or higher, germination than the 2-year-old seed stored at 40 degrees F.

Seed from the inverted glass container, exposed to the sun, failed to give as good germination as seed stored in the muslin bags at high temperature.

Seed irrigated November 5 had given relatively high percentages of seedling stand by December 1. For most lots, stands were considerably better than were obtained for the first planting. This was possibly due to cooler soil temperatures and "ageing" of the seed. The greatest increase occurred for the lots stored at 40 degrees F. Germination of seed from this storage temperature compared favorably with that stored at higher temperature for this late planting, whereas at the earlier planting, as has been shown, actual stands were much lower. For example, the October 13 count of stand for 152 and 615 stored air tight at 40 degrees F was 17 and 21, respectively, while for the second planting, it was 74 and 63, on December 1. A similar situation is noted for the 75 per cent humidity lots.

Comparison of the two varieties for December 1 stand shows that there is no consistent difference between the two, as had been found for the earlier planting, when Imperial 615 gave consistently better stands.

### CONCLUSION

Because of the preliminary nature of this work, it is thought inadvisable to stress the importance of many of the significant differences noted. The sensitivity of lettuce seed to a great many environmental

factors at time of germination has long been known. It was obvious in this study that individual seeds within each of the experimental lots exhibited varying, and, most likely, ever-changing reactions towards germination environment, so that their behavior under one set of conditions could not be used for exact prediction of their relative behavior under another set of conditions. The present report offers an indication that storage environment of "new" seed may exert a more important effect on germination, within a few months following harvest, than had been anticipated. Other workers (2, 3) have demonstrated the effectiveness of low temperatures in breaking dormancy of moist lettuce seeds, and of high temperatures in reverting moist seeds to a dormant condition. Data in the present paper show that high temperature storage of "dry" seed may be effective in breaking dormancy, and that high temperature storage of "new" seed which is to be planted within 6 months after harvest may be desirable.

Seed of Imperial 615 gave an earlier satisfactory field germination than seed of Imperial 152.

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## Viability of Freshly Harvested Celery Seed

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**A** PRELIMINARY study of the feasibility of producing celery seed in the greenhouse during winter provided an opportunity to investigate the viability of freshly harvested mature seed. The former was proven, and, thus material for this paper was provided.

### EXPERIMENTAL

Five plants of Golden Plume were placed in 6-inch plant pots early in November 1937, immediately after being removed from an outdoor cellar where they were stored with sphagnum moss packed around their roots. The plants were quite severely frozen, and after being trimmed, potted, and watered, they were placed in a cool storeroom, (temperature around 45 to 55 degrees F) to permit them to thaw out slowly. Recovery from the freezing was fairly rapid, and the plants were placed on a well lighted bench in the greenhouse in about 3 weeks.

Careful attention was paid to watering, insect control, and other details of culture in order to encourage vigorous growth. Development was considered satisfactory and blossoms opened on one plant (hereafter referred to as no. 1) on March 10, 1938. No. 2 plant was in bloom on March 19 and no. 3 on March 22, 1938. No. 1 in full bloom and no. 3 at the beginning of the flowering period are shown in Fig. 1. The vigor of the main stem is apparent, and also the numerous umbellets on the many branches of the flower stem. Plant no. 4 blossomed on April 8 and no. 5 on April 18, (no. 5, however, was not included with the remainder in the seed germination studies on account of its coming into blossom so late).

The first seeds were harvested on May 27, when the earliest developed (or most mature) seeds on plants nos. 1 and 2 had assumed a deep brown appearance, a color considered as indicating a fair degree of maturity or ripeness. After the seeds were harvested by clipping and removing



FIG. 1. Typical celery plants grown in greenhouse during winter for seed production. No. 3 plant on left at beginning of flowering period. No. 1 plant on right in full bloom. (Photographed March 23, 1938.)

the pedicels of the umbellets and individual flowers, three lots of 100 seeds each were counted at random from the seeds harvested from each plant.

One lot (a) of 100 seeds was sown immediately in a shallow seed pan in a soil mixture composed of equal parts clay loam, granulated peat, and coarse builders' sand. Another lot (b) of 100 seeds was air-dried at room temperature for 2 weeks (around 70 degrees F), and another lot (c) of 100 seeds was placed in an electric refrigerator for 2 weeks in a temperature of about 40 degrees F before being sown in similar containers and soil.

To corresponding samples of seeds secured from plants nos. 3 and 4, respectively, at approximately the same stage of development, similar treatments were given.

The seed pans were placed on a sand propagating bench, and over each was placed a bell-jar of suitable size. Counts of seedlings which had emerged were made at various intervals. Seedlings which had emerged were discarded at the time counts were made. The bell-jars were removed from the seed pans on August 10, when all the seed pans were placed on the open greenhouse bench. (Bell-jars were removed from nos. 1a and 2a on July 8.) The last emergence count was made on September 21 although the seed pans were not disturbed and discarded until October 15, 1938.

Notes as to development of seedlings when emergence counts were made were to the effect that plants varied in size from seedlings nicely germinated with only two seed leaves to those with from two to four true leaves.

TABLE I—EMERGENCE OF CELERY SEEDLINGS (1938)

Plant No., Treatment	Date Seeds Sown	Number of Seedlings Emerged (Days from Time of Sowing Seed)				
		14	21	28	Later Time	Final (Per Cent) Emergence
1 a . . . . .	May 27	53	58	59	67 (75)*	67
b . . . . .	June 10	46	46	46	90 (61)	90
c . . . . .	June 10	27	29	31	81 (61)	83
2 a . . . . .	May 27	9	46	66	85 (75)	85
b . . . . .	June 10	17	32	41	93 (61)	93
c . . . . .	June 10	10	13	21	89 (61)	91
3 a . . . . .	June 10	35	52	67	96 (61)	96
b . . . . .	June 24	2	Not	19 (47)	96 (90)	96
c . . . . .	June 24	3	counted	6 (47)	95 (90)	95
4 a . . . . .	June 24	5	6 (47)	84 (90)	—	84
b . . . . .	July 8	Not	6 (33)	66 (75)	—	66
c . . . . .	July 8	counted	35 (33)	73 (75)	—	73
Average						
a . . . . .	—	—	—	—	—	83.00
b . . . . .	—	—	—	—	—	86.25
c . . . . .	—	—	—	—	—	85.25

\*Figures in brackets indicate the number of days between the date of seed sowing and the date the seedlings were counted and removed from the seed pans.

### DISCUSSION OF RESULTS

Average figures for the final percentage emergence of seedlings by plants place the plants in the following order: first, no. 3 (95.75 per cent); second, no. 2 (89.67 per cent); third, no. 1 (80.00 per cent); fourth, no. 4 (74.33 per cent). With plants, nos. 1 and 4 respectively,

final emergence figures suggest that treatments exerted an influence not manifested by the other two plants. If an influence on emergence was exerted, however, it did not do so uniformly since emergence counts for these two plants (nos. 1 and 4) in the various treatments are respectively (a) 67 and 84, (b) 90 and 66, (c) 83 and 73; *i.e.* if we surmise that emergence was depressed by treatment (b) in one case, no depression was manifested in the other. For the other plants differences in final emergence counts cannot be considered significant.

The average emergence counts for each treatment of all plants, namely (a) 83.0 per cent, (b) 86.25 per cent, and (c) 85.25 per cent, indicate that treatments did not influence emergence of seedlings to any significant degree, and that, for the period of the study, no advantage would be gained by air-drying or chilling newly harvested seed prior to planting it, if it is mature or available for planting at the time celery seed is usually sown or needed for crop production.

A reason for the irregularity of emergence as between plants and as between intervals recorded is suggested. (An alternative reason is proposed in a later paragraph!). As previously stated and as shown in Table I, the date of sowing the first seeds for the respective plants varied from May 27 to June 24, with dates for treatments (b) and (c) ranging from June 10 to July 8. Greenhouse and controlled (more or less) conditions accepted, climate and environment vary and change rapidly at that time of year from being cool and humid to warm and dry. The seed pans were situated on moist sand propagating benches in the greenhouse with bell jars over them as stated previously, and, though watered occasionally, it is believed that conditions were too dry for the germination of the majority of the seeds. A certain amount of moisture would find its way into the bell jar chambers by condensation, evaporation and capillarity, but not in quantities necessary for celery seed germination.

Evidence supporting this explanation is deduced from the fact that emergence took place quite rapidly after the bell jars were removed, the seed pans placed on the greenhouse bench, and water given in greater quantities and more frequently than formerly. The need of carefully controlled moisture conditions especially was made manifest from the study, and will be provided for, as further progress is made with the problem.

While the evidence is meager, there is at least regularity in the germination of seeds of plants 1, 2 and 3, up to the 28th day, namely, that refrigerator treatment at 40 degrees F caused more delayed emergence than air-drying at room temperature. There was no such regularity in final emergence counts.

A germination test might be made under seed testing laboratory conditions, but one of the aims of the study is to produce and germinate seed in a manner which might be adopted by the commercial grower. Pre-germination might be encouraged in the manner outlined by Thompson (3) *viz.* "Soaking the seed, prior to planting, hastens germination and is practised by growers in many sections, especially for the late crop of celery. A common method is to moisten the seed in a pan or other receptacle and put in a warm place where it is kept for

several days or until the sprouts begin to appear. Another method followed by some growers is to place the seed between folds of cloth. The cloths are kept moist."

The alternate explanation for the slow emergence of seedlings is that with the coming of warmer, drier days, the seeds underwent a temporary or regular dormancy or after-ripening. This phenomenon is encountered in connection with seed germination of many economic plants. In his investigations on the germination of seeds Harrington (1) found that seeds of celery along with others germinate much better with favorable alternations of temperature than at constant temperatures, the exact alternation depending on the kind of seed. He emphasized the desirability of maintaining the upper temperature for only part of a day and that the change to the lower temperature should be fairly rapid. For celery the best results were obtained when the low temperature continued at 20 degrees C (68 degrees F) for 16 to 18 hours, and the high temperature continued at 30 degrees C (86 degrees F) for 6 to 8 hours. It is believed that the temperatures which prevailed during the study reported here would correspond very closely to these recommended by Harrington, the short period corresponding to the midday period of high temperature, and the longer period the remainder of the day. The recent study reported by Odland (2) at Minnesota indicates that cucurbit seeds have a weak after-ripening period, germination being rapid after the seed was 4 weeks old, and if fruits were allowed to become over-ripe.

### CONCLUSION

Conditions favoring rapid and uniform germination of celery seed have been discussed. This has seemed a logical correlation to the main object of the experiment, namely, investigating the feasibility of producing celery seed in the greenhouse in winter. Development of seed-stalks took place satisfactorily, and viable seed was produced in the greenhouse in winter without the aid of artificial illumination.

The percentage emergence of newly harvested seed from different plants varied during the early intervals when emergence counts were made. These differences were less pronounced when final emergence counts were made at the conclusion of the experiment.

Some evidence was secured that germination was delayed by exposing the seed to a temperature of about 40 degrees F for 2 weeks. Air-drying the seed for 2 weeks did not seem to influence greatly the viability of the seed, and average final emergence counts for all treatments and all plants, were not significantly different. Lack of sufficient moisture for proper germination of the seed is believed to account for its low germination early in the experiment.

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# The Maintenance of Seed Stock of the Porto Rico Sweet Potato

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THE most practical means of improving and maintaining the existing commercial varieties of sweet potatoes in this country has been through constant selection for type. This fact is borne out in the work of Harter (1), Groth (2), Miller (3), Rosa (4), and Thompson (5).

It is known that some of the varieties grown at the present time originated as a result of mutations and others may have had similar origin. Interest is now being taken in the improvement of sweet potatoes by breeding, since methods of obtaining true seed in the South have been found and new varieties probably will be originated. However, in order to maintain the true type of new varieties constant selection will be essential.

As Miller has pointed out, mutations in sweet potatoes occur frequently. Under field conditions in Louisiana, an average of one visible mutation occurred in every seven thousand plants. Although these studies were made with the Porto Rico variety, it is likely that mutations occur frequently with most other varieties. Most of these mutations are retrogressive in nature, but there is an occasional mutation which results in an improvement of the type. An example is the Louisiana Porto Rico Unit One developed by Miller.

Commercial sweet potato growers in Louisiana and other states are rapidly adopting the Unit One strain because of its superiority. This strain has a more desirable color, *viz.*, copper red skin and salmon-pink flesh. It is a better yielding strain than the seed stock of this variety found on the average Louisiana farm. Demonstration plantings made in 1937 by 24 St. Landry Parish 4-H club boys, who compared the Louisiana Porto Rico Unit One with the strain of Porto Rico then in use on their fathers' farms, showed that the Unit One out-yielded the other strains by 15.2 per cent.

An external examination of each sweet potato intended for seed will readily show whether the skin color is desirable, but in order to check the flesh color it is necessary to nick each potato on the shoulder at the proximal end. If the area nicked shows a salmon-pink flesh the specimen meets the requirement of the Porto Rico variety. However, if nicked area shows the color to be undesirable, the potato should not be used for seed as the slips or draws from such seed stocks are likely to produce a crop of potatoes which will be off-color.

This method of selection is a practical means of maintaining the desired color when the Porto Rico variety is used.

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# Growth, Production, and Fruit Quality of Tomatoes Grown Under Cloth

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THE most serious difficulties encountered in producing tomatoes in Oklahoma are due to climatic conditions such as high temperature, intense sunshine, low humidity and drying winds. Failure to get fruit set and sunscald are major problems. It was thought that "Aster" cloth, the type used by florists and tobacco growers, might afford sufficient protection from intense sunshine, wind, and other factors to secure a better set of fruit, eliminate sunscald, and extend the harvest season into late summer.

A trial was conducted in 1938 to compare the growth, production and fruit quality of tomatoes grown under cloth with the general methods of culture. The methods used were: (a) plants unpruned and untrained, spaced 4 feet by 4 feet; (b) plants pruned to a single stem and trained to stakes, spaced 2 feet by 3 feet; (c) same as treatment (b) and enclosed by a cloth house. All blocks were equal in size, 70 plants being used under the first method and 156 in each of the staked plots. Two varieties, Marglobe and Gulf State Market, were used, half of each plot being planted with each variety.

Although the season was quite favorable for tomatoes under ordinary methods of culture, there were considerable differences in favor of the cloth protection.

Data in Table I show the comparative growth, flower development and fruit set of the staked plants shaded and unshaded.

TABLE I—THE EFFECT OF CLOTH SHADE ON GROWTH AND FRUIT SET OF STAKED TOMATOES\*

Variety	Average Number Flowers per Cluster (a)	Average Number Fruit Set per Cluster (a)	Per Cent Set (Based on Total Numbers)	Average Height of Plants September 10	Average Stem Diameter (b) (Cm)	Average Length Internodes (c) (Inches)
<i>Marglobe</i>						
Shaded . . . . .	6.4 ± .109	4.4 ± .106	58.6	9' 10"	1.32	2.48
Unshaded . . . . .	5.7 ± .126	2.7 ± .163	47.2	8' 1"	1.58	2.07
Difference . . . . .	.7**	1.7**	—	—	—	—
<i>Gulf State Market</i>						
Shaded . . . . .	6.5 ± .127	3.8 ± .105	58.1	12' 0"	1.43	2.81
Unshaded . . . . .	5.9 ± .159	3.3 ± .084	56.8	9' 10"	1.56	2.50
Difference . . . . .	.6**	.5**	—	—	—	—

\*Data taken on 22 plants of each variety under each treatment.

\*\*Odds of significance excell the 5 per cent point.

(a) Figures on first 4 clusters on Marglobe and first 5 clusters on Gulf State Market.

(b) Greatest diameter, taken at internodes below each of the first 8 clusters.

(c) Measurements of 20 internodes on each plant.

The plants grown under cloth produced a larger number of blossoms and a higher per cent of the blossoms set fruit. This fact is further emphasized by the difference in number of fruits produced as shown

in Table II. The shaded plants made a more succulent growth as indicated by the measurements presented in Table I.

TABLE II—YIELD RECORDS OF TOMATOES GROWN UNDER THREE METHODS OF CULTURE

Variety	Untrained, Unstaked			Trained, Staked			Trained, Staked Grown in Cloth House		
	Number of Fruits	Weight of Fruits (Pounds)	Average Weight per Fruit (Ounces)	Number of Fruits	Weight of Fruits (Pounds)	Average Weight per Fruit (Ounces)	Number of Fruits	Weight of Fruits (Pounds)	Average Weight per Fruit (Ounces)
Marglobe	828	152.7	2.95	1195	290.9	3.89	1582	424.7	4.29
Gulf State	972	162.3	2.66	1485	326.3	3.53	1845	443.6	3.85
Market									
Totals . . .	1800	315.0	2.80	2680	617.2	3.68	3427	868.3	4.05
Average yield per plant .	—	4.50	—	—	3.96	—	—	5.63	—
Average yield per sq. ft. . .	—	.28	—	—	.66	—	—	.93	—

The harvest period extended from June 27 to September 8. Fruits started maturing at approximately the same time on all three plots but the early yield from the unpruned-untrained plot was quite low. During the last of the season, August and September, the number of fruits harvested on the staked, unshaded plot was much less than from the other two. The fruits from the cloth house the last few weeks were much larger in size than those from the unstaked, unpruned plants, which indicates the value of cloth protection for extending the producing season of marketable fruits into late summer in this locality. A record of various factors affecting the quality of fruits is given in Table III.

TABLE III—FACTORS AFFECTING THE QUALITY OF TOMATOES

	Untrained and Unstaked		Trained and Staked		Trained, Staked, Grown in Cloth House	
	Marglobe	Gulf State	Marglobe	Gulf State	Marglobe	Gulf State
Number fruits showing rot when harvested . . .	174	170	26	39	20	25
Number fruits sunscalded	64	83	9	9	0	0
Number fruits with blossom end rot	1	9	3	15	0	0
Per cent of fruits cracked*	34	31	69	48	59	63

\*Cracked sufficiently to make them unmarketable (for harvests from August 5 to September 8).

The coloring of the fruits grown under cloth was noticeably more uniform and a deeper red due to the partial shade. Sunscald and blossom end rot, although not serious this year due to favorable weather, were eliminated by shading. This effect is expected to be much more

important during the warmer, drier seasons which usually occur in this state.

Cracking of the fruits, which became serious during the last of the season, was less severe on the unstaked plants. This is in agreement with work reported by Frazier (2). In the present study the variety Marglobe cracked less but Gulf State Market cracked more when shaded. Frazier (2) and Brown and Price (1) reported a reduction of cracking when the plants or fruits were shaded.

#### CONCLUSION

Cloth shade increased the number of flowers developed per cluster and the percentage of flowers which set fruit of tomatoes. Pruned and staked plants had a smaller stem diameter but greater length of internodes and total height when shaded. Shaded plants produced a significantly larger number of fruits and greater total weight than unshaded plants. Sunscald and blossom end rot were prevented by shading.

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# The Effect of Storage Methods on Ripening and Quality of Tomatoes<sup>1</sup>

By ELEANOR A. WEST and GRANT B. SNYDER, *Massachusetts State College, Amherst, Mass.*

**B**ECAUSE of the increasing demand for tomatoes throughout the year, and the high price of the fruit during the winter months when northern areas cannot produce this crop, some satisfactory method of storage which might hold the late crop for a few weeks after the normal season would be of great advantage to both producers and consumer. The main purpose of this investigation was to determine the marketable storage life of tomatoes, and the effect of washes, waxes, and various types of wrappers on the keeping quality of such stored fruits, considered from a chemical, physiological, and pathological viewpoint.

The tomatoes used in these experiments were greenhouse grown and of the variety Comet. Two experiments were performed, the second checking the results obtained in the first, and including several treatments not used in the first experiment.

In experiment I there were two groups of eight lots each, one group composed of fruits in the pink stage of maturity according to the standards of the United States Department of Agriculture, and referred to in the discussion as the green fruits, the other group composed of firm, ripe fruit. Each lot contained 30 fruits.

The two groups were treated similarly. One control lot from each group was used immediately for analytical work. The remaining lots were stored after receiving the following treatments: untreated; wrapped in cellophane, parchment, and tissue; dipped in sodium borate solution, formaldehyde solution, and coated with paraffin over the stem scar. Each fruit of all the lots, except the controls not stored, was weighed individually.

The tomatoes in experiment II were all at the firm ripe stage of maturity and fully colored. There were 14 lots, each containing 15 fruits except the control which contained 12, and the control with calyx attached which contained 13. No unstored control was used, as analyses of chemical changes were not to be studied after storage. The lots were treated as follows: control, control with calyx, borax washed, formaldehyde washed; and the following, one lot of each washed with formaldehyde before the treatment and one lot with the treatment alone: cellophane, parchment and tissue wrapped, paraffined at the stem end, and wax coated. The tomatoes were weighed individually as in experiment I.

A white vegetable parchment, 20 pound basis weight, a colorless transparent cellulose paper, No. 300 P: H: T grade, and a green tissue of the type commonly used to wrap apples, all cut to 9 by 9 inches, were the wrappers used.

The borax wash was a 5 per cent sodium borate solution, with a

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<sup>1</sup>Contribution No. 336 of the Massachusetts Agricultural Experiment Station.

0.5 per cent tar soap included as a wetting agent, and was used at a temperature of 40 degrees C. The formaldehyde solution, a 1:300 dilution of commercial 37 per cent grade, was used at a temperature of 20 degrees C. The waxed tip treatment consisted of an application of pure paraffin sufficient to cover the stem scar. A wax emulsion, formulated by the Franklin Research Company, formula number 489-A, was used in coating the entire fruit. For the sake of simplicity, the name of the treatment is used in the discussion to indicate the lot treated in such a manner.

After treatment each lot was placed in a wooden flat, the bottom of which was covered with paper toweling to prevent bruising of the fruits. Since the fruits were in a single layer, and small blocks separated the stacked flats, ventilation was ample.

During the first experiment the temperature of the storage room ranged from 45 to 55 degrees F, while in the second experiment the range was from 45 to 49 degrees F. The relative humidity was not determined in the first experiment; in the second it varied from 45 to 48 per cent.

All lots were inspected frequently and were removed when the maximum length of storage appeared to have been reached without excessive losses due to decay and disease. The ripe lots of experiment I were removed after being in storage 20 days, and the green lots after 30 days. The fruits in experiment II were in storage 30 days.

After storage, color and weight were again determined; each fruit was examined for disease and breakdown and tested for firmness with a Chatillon penetrometer. Acidity and hydrogen-ion concentration were then determined with a glass electrode, and ascorbic acid content by Tillman's method as modified by Bessey and King. Total solids, ash, nitrogen, reducing sugars, ether, crude fiber, and total soluble solids, ash and nitrogen were determined from dried samples.

During storage, the green fruits colored well, though they did not attain the deep red of the ripe lots, being more orange-red and of a lighter shade. No noticeable difference in color between lots was observed. The pressure test on the whole fruit showed the green lots in each case to be firmer than the ripe lots of a similar treatment. When the skin was removed, however, the green lots were firmer only in the tissue and parchment wrapped, waxed tip, and borax washed lots.

In experiment I the waxed tip treatment had firmest fruits after storage, when the whole fruit was considered. When tested with the skin removed, the tissue wrapped fruit was firmer. In experiment II, the cellophane, and washed cellophane lots were firmer when tested with the skin on, and the latter treatment also gave the best results in tests with the skin removed. There was considerable variability in the pressure readings, however, which in part accounts for differences in results in the two experiments.

Percentage loss in weight was calculated for individual fruits and the mean with the probable error for each lot in both experiments is given in Table I. The green fruit had a higher percentage loss in weight than the ripe in five of the seven lots, and in one treatment the

TABLE I—LOSS IN WEIGHT (PER CENT)

Treatment	Mean	Probable Error of the Mean	Coefficient of Variability
<i>Experiment I</i>			
Control green . . . . .	4.91	±.24	39.3
Cellophane green . . . . .	5.76	±.25	34.9
Parchment green . . . . .	6.04	±.28	36.2
Tissue green . . . . .	5.16	±.19	29.1
Waxed tip green . . . . .	4.62	±.25	42.8
Formaldehyde green . . . . .	5.47	±.27	37.1
Borax green . . . . .	5.88	±.13	17.5
Control ripe . . . . .	5.49	±.40	57.9
Cellophane ripe . . . . .	5.62	±.23	35.2
Parchment ripe . . . . .	6.04	±.40	52.8
Tissue ripe . . . . .	3.78	±.18	38.9
Waxed tip ripe . . . . .	3.38	±.35	82.8
Formaldehyde ripe . . . . .	4.35	±.33	60.9
Borax Ripe . . . . .	5.25	±.31	47.4
<i>Experiment II</i>			
Control . . . . .	7.64	±.55	35.6
Control with calyx . . . . .	7.37	±.19	13.3
Cellophane . . . . .	5.92	±.12	11.6
Cellophane washed . . . . .	7.04	±.24	18.6
Parchment . . . . .	6.42	±.18	15.9
Parchment washed . . . . .	6.68	±.16	13.3
Tissue . . . . .	6.53	±.30	25.0
Tissue washed . . . . .	6.96	±.28	22.3
Waxed tip . . . . .	5.65	±.16	16.1
Waxed tip washed . . . . .	6.61	±.27	22.2
Waxed . . . . .	5.42	±.18	18.5
Waxed washed . . . . .	6.21	±.20	18.3
Formaldehyde . . . . .	7.05	±.15	11.6
Borax . . . . .	6.97	±.40	32.1

loss in green and ripe lots was the same. In both the green and the ripe fruits the loss in weight was greatest in the parchment wrapped lots and least in the waxed tip.

In experiment II, the loss in weight was least with the waxed treatment, and greatest with the control. In the five pairs of treatments which were applied with and without previous washing with formaldehyde, the washed lots consistently lost more weight than the corresponding unwashed lots.

Normal loss in the weight of tomatoes during storage is due to respiration and evaporation. The difference in loss in weight between the green and ripe fruits might be explained by a report by Gustafson (1) concerning the ripening of fruit on the vine. He stated that during normal growth the rate of respiration decreases, reaching a minimum at the green mature stage of maturity; it increases during ripening to a maximum when the fruits are orange to red in color, after which it again decreases. If the same changes in the rate of respiration occur during the artificial ripening of fruit, the green fruits, respiring more rapidly than the ripe fruits, would be expected to lose more weight. This is substantiated by the results given in the table. The coefficients of variability, however, showed the ripe lots to be much more variable in loss in weight than the green lots.

Results of the chemical analyses are given in Tables II and III. As the chemical analyses were made on composite samples, there was no way of testing statistically the value or significance of the results obtained. They can however be assumed to show trends.

TABLE II—ANALYSIS OF THE SAMPLE (FRESH BASIS)

	Moisture (Per Cent)	Solids (Per Cent)	Ash (Per Cent)	Protein* (Per Cent)	Reducing Sugars† (Per Cent)	Ether Ex- tract (Per Cent)	Crude Fiber‡ (Per Cent)	Ascorbic Acid (Mg/Gm)	pH	cc N/10 NaOH**
<i>Fruit Stored Green</i>										
Control . . .	94.6	5.4	0.44	1.56	1.04	0.16	0.52	0.179	4.6	0.40
Cellophane . .	94.5	5.5	0.41	0.94	2.00	0.15	0.47	0.194	4.4	0.56
Parchment . . .	94.4	5.6	0.44	1.06	1.83	0.18	0.53	0.223	4.6	0.37
Tissue . . . . .	95.4	4.6	0.38	1.31	1.23	0.14	0.44	0.201	4.6	0.42
Waxed tip . . .	94.7	5.3	0.42	1.56	1.63	0.16	0.47	0.136	4.6	0.35
Formaldehyde .	94.6	5.4	0.42	1.00	1.77	0.16	0.49	0.179		
Borax . . . . .	95.2	4.8	0.38	1.44	1.44	0.15	0.47	0.144	4.6	0.55
<i>Fruits Stored Ripe</i>										
Control . . . . .	95.7	4.3	0.36	0.81	1.29	0.14	0.40	0.172	4.6	0.40
Cellophane . . .	95.4	4.6	0.44	1.25	1.01	0.13	0.48	0.168	4.5	0.21
Parchment . . .	94.5	5.5	0.52	1.13	1.21	0.16	0.58	0.187	4.5	0.40
Tissue . . . . .	94.9	5.1	0.43	1.00	1.42	0.15	0.48	0.172	4.6	0.32
Waxed tip . . .	95.6	4.4	0.42	1.31	1.00	0.14	0.47	0.172	4.5	0.40
Formaldehyde .	95.6	4.4	0.42	0.88	1.03	0.13	0.47	0.203	4.5	0.40
Borax . . . . .	94.6	5.4	0.52	1.19	1.22	0.17	0.55	0.172	4.3	0.52
<i>Controls Not Stored</i>										
Green . . . . .	96.4	3.6	0.28	0.69	1.09	0.10	0.43	0.130	4.6	0.52
Ripe . . . . .	94.2	5.8	0.71	1.06	2.48	0.17	0.53	0.168	4.5	0.64

\*Total nitrogen  $\times 6.25$

\*\*ccN/10 NaOH to neutralize 1 gram fresh material

†Calculated as glucose

‡Determinations made by Mr. Philip Smith of the Experiment Station

TABLE III—ANALYSIS OF THE SAMPLE (IN PER CENT) (FRESH BASIS)  
SOLUBLE SOLIDS, ASH, AND NITROGEN\*

		Green Fruit		Ripe Fruit	
		Not Stored	Stored	Not Stored	Stored
Water	Solids	2.63	4.26	4.57	3.41
	Ash	0.28	0.44	0.71	0.36
	Nitrogen	0.049	0.108	0.086	0.068
Hydrochloric acid	Solids	2.62	4.16	4.47	3.40
	Ash	0.28	0.44	0.71	0.36
	Nitrogen	0.054	0.110	0.088	0.066
Sodium carbonate	Solids	2.78	4.36	4.74	3.51
	Ash	0.28	0.44	0.70	0.36
	Nitrogen	0.057	0.119	0.089	0.080
Hydrochloric acid + pepsin	Solids	2.75	4.26	4.67	3.57
	Ash	0.28	0.44	0.71	0.36
	Nitrogen	0.069	0.137	0.112	0.087
Sodium carbonate + trypsin	Solids	2.69	4.47	4.18	3.58
	Ash	0.27	0.45	0.69	0.36
	Nitrogen	0.078	0.166	0.106	0.095

\*Figures represent soluble constituents in relation to totals.

Ascorbic acid was present in lowest amount in the green lot not stored. An average of all the green lots and all the ripe lots showed

little difference in ascorbic acid content between these two groups.

Hydrogen-ion concentration showed little variation among the samples, the green and ripe groups averaging practically the same. In agreement with the results of Sando (2) titrable acidity was found to increase during ripening.

The lot harvested green and not stored, contained the least solid material, and the lot ripened on the vine and not stored contained the most. The green lots apparently lost much more moisture during storage than did the ripe lots; for after storage, the green lots contained a higher percentage of solids, and the ripe lots a lower percentage, than before storage. This statement is supported by the consideration that the average of the percentage losses in weight is greater for the green than for the ripe lots and evaporation is a much greater cause of loss in weight during storage than respiration.

When calculated on the basis of the fresh weight, the percentage differences in the results of the chemical analyses for the various constituents depended, to a large degree, on differences in percentage of dry weight. On the basis of the air dry and oven dry samples, some rather large differences in composition appeared, but when calculated to the fresh weight basis, these differences were masked by the large amount of water present in the fresh fruit. Sugars and acids were probably the most important constituents modifying the flavor and hence the quality of tomatoes. These varied rather widely in the different lots, but variations within the green and the ripe groups did not show any consistent differences, though the green lots retained more of their reducing sugars than the ripe lots. This might be expected on the basis of Rosa's (3) statement that reducing sugars increase during normal ripening.

Total soluble solids, ash, and nitrogen for the four controls are given in Table III. Examination of the table shows that the amount of soluble material was lowest in the green lot not stored, with the ripe-stored lot, green stored, and ripe not stored higher in the order stated. Solubility in water and in hydrochloric acid did not differ greatly and was in both cases lower than in the sodium carbonate solutions. The amount of soluble solids, however, would affect flavor only insofar as the amount of sugars in the soluble solids varied.

In experiment I the incidence of disease was twice as great in the ripe as in the green lots. The lots treated with disinfectant and the controls showed a smaller number of diseased fruits than any of the other lots, while the greatest incidence of disease was found in the cellophane and parchment wrapped lots. In experiment II, however, the occurrence of disease was lowest in the washed-cellophane lot, with washed-waxed, and washed-tissue next; this shows the value of disinfection when protection against further contamination is given. An average of the washed lots showed 33.3 per cent of the fruits diseased, while in those not washed, but otherwise treated the same, 68.9 per cent of the fruits were diseased.

Total shrinkage, considering loss in weight and in marketability due to disease, was, for the green lots, 17 per cent, for the ripe lots 25 per cent, and for experiment II, 30.7 per cent. Comparing the

unwashed lots with the similarly treated washed lots of the second experiment, the average for the former is 42.4 per cent and for the latter 25.3 per cent.

The disease which caused the greatest loss in the stored fruits was Phoma rot (*Phoma destructiva* Plowr.). Several other molds were present but were of little importance or were secondary infections.

A form of physiological breakdown was noted, particularly in experiment II. On the surface of the fruit, it appeared as a mottling of the flesh with lighter colored areas, not distinct but as a diffused wide whitish venation. When the epidermis was removed, it was seen that the whitish area followed the vascular system. A cross section of the fruit showed the cells of these areas to have a silvery white appearance, which Weber and Ramsey (4) explained as signifying a lack of moisture. For the most part, the breakdown was very near the epidermis, but occasionally it followed the vascular bundles a slight distance into the inner walls. Weber and Ramsey referred to the condition as "cloudy spot", and stated that there is no organism associated with it, and found that it seemed to be confined to individual plants, as the fruits did not show it previous to storage, but was due rather to some environmental factor affecting the fruits after harvest and during storage. Though the cause of the abnormality is not known, it is possible that temperature during storage, combined with the loss of moisture might be, at least in part, the cause of the condition.

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# Performance in Hawaii of Tomato Strains Developed for the Southern States<sup>1</sup>

By J. E. WELCH, *Hawaii Agricultural Experiment Station,  
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**L**ITTLE experimental work in Hawaii has been directed toward the isolation of superior varieties of the principal vegetable crops. As a result, practically no vegetable varieties in the Territory have been developed for these latitudes, and strains evolved for the continental United States are grown. In initiating a tomato improvement program, it was thought advisable to make a careful survey of the important varieties grown in Hawaii and on the mainland, and to check these against a number of hybrid selections developed under climatic conditions approaching those of the Territory.

After 2 years the results of three tests are available. One other trial was planted during the period but was not harvested due to a severe virus infection.

## MATERIALS AND METHODS

The experiments were conducted at Waipahu, at an elevation of 400 feet. The rainfall, which averaged approximately 35 inches per annum, was confined mostly to the late fall, winter, and early spring months; the days were normally bright, and irrigation was practiced. The plot was in sugarcane prior to the first tomato planting, and the soil proved to be quite fertile.

A total of 73 varieties and strains of tomatoes have been included in the tests. The sources were as follows: 31 unnamed hybrid selections and four strains of commercial varieties from W. S. Porte working in Florida with the United States Department of Agriculture; four unnamed hybrid selections and three unnamed selections from J. C. Miller of the Louisiana Agricultural Experiment Station; two unnamed hybrid selections from W. K. Bailey of the Puerto Rico Agricultural Experiment Station; five unnamed hybrid selections and six strains of commercial varieties from M. Takahashi of the Hawaii Agricultural Experiment Station; one commercial variety from the New Jersey Agricultural Experiment Station; three commercial varieties from the California Packing Corporation; and 14 commercial varieties from commercial seedsmen of the United States.

The first test was transplanted to the field on August 14 to 18, 1936, and consisted of 36 unnamed accessions from Florida and Louisiana, and 18 commercial varieties. The accessions were divided into three groups and the introductions in each group occurred in three randomized blocks. Harvesting began 57 days after transplanting and continued for 73 days. Due to undesirable characteristics, ten unnamed strains and six commercial varieties were eliminated after this test.

The remaining accessions plus three new commercial varieties were

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included in a second test, which was transplanted to the field on February 3, 1937 in three randomized blocks as a single experiment. Harvesting began 68 days after transplanting and continued for a period of 88 days. Four unnamed accessions and the three new commercial varieties were eliminated after this trial.

The third test consisted of 34 of the older introductions and 14 new acquisitions, of which eight were unnamed accessions from Florida, Puerto Rico, and Hawaii, and six were commercial strains. The plants were transplanted to the field as a combined experiment in five replications on August 18, 1937. After several weeks, every plant in the field had become affected in varying degrees with a virus disease closely resembling spotted wilt, so no yield records were gathered. Seed were saved from all plants showing apparent resistance and from all accessions which had proven in past tests to be desirable, high-yielding types. The seed were harvested from open-pollinated individual plants and held separately. Eleven unnamed accessions and six commercial varieties were discarded after the test.

The fourth trial, planted in February and March, 1938, included 65 open-pollinated individual plant selections from 33 accessions, of which 14 unnamed introductions and seven commercial varieties appeared in each of the three previous tests. Only 10 of the 14 new strains in the third test were continued, 5 of which were unnamed and 5 commercial strains. A new unnamed hybrid selection from Puerto Rico and an additional commercial variety were included for the first time. Due to the large number of accessions, planting took place in three installments or sections, at approximately 3-week intervals. The same six checks were used in each section so that varieties in different groups could be compared. The experiment was planted in randomized blocks, as in the previous trials, and five replications were used. For the most part the plants in this test appeared remarkably vigorous and healthy, and the performance of the varieties and strains showed no relation to their past susceptibility to "spotted wilt". Harvesting on these plantings began 57, 56, and 58 days after transplanting and lasted for 67, 64, and 43 days, respectively. The harvest period was shortened in the last division due to the increasing seriousness of the "spotted wilt" virus.

The combined results from the first two tests and the data from the fourth test were interpreted according to the methods employed by Immer, *et al.* (1) and Snedecor (2). Analyses were on the basis of yields of No. 1<sup>2</sup> and No. 2 fruit combined, and total yields of No. 1 and No. 2 fruit and culls. In each of the three successful tests, rather complete descriptive data were also obtained, including notes on market quality of fruit (size, shape, color, stem scar, blossom scar, smoothness, flesh color, and cracking), as well as on plant characteristics. Both yields and descriptive data have been used as criteria to eliminate apparently undesirable strains.

<sup>2</sup>No. 1 fruits had a minimum diameter of 2¼ inches and in ripeness were at least "green mature". In other respects they were graded according to U. S. No. 1 standards although somewhat more strictly. No. 2 fruits were classified in a similar manner except the minimum diameter was 1¾ inches and grading was not as rigid.



## PRESENTATION OF RESULTS

A complete discussion of the results of the three tests is impossible in the time and space available. The field plot methods and the methods of analyses were satisfactory; however, after the low yielding and poorly adapted strains were eliminated, it was found that larger plots and more replications will be necessary in future tests to determine significant differences. Such experimental differences in yield as well as the grower and consumer acceptance of varieties will be determined over a period of years and in different locations.

On the basis of the yield data obtained in the three yield tests, together with an abundance of descriptive data, all except 14 introductions have been eliminated. Listed in Table I are the accession numbers, names and sources of the introductions retained, and yields of No. 1 and No. 2 fruit. The acre yields are based on the average of the first and second tests for the 10 accessions for which such average yields are available. In the last test the same general relationship existed among these 10 strains with one exception, that Grothen's Globe did not yield quite as well as previously. The yields given for the other four introductions are from the fourth test.

TABLE I—ACCESSIONS SELECTED FOR FURTHER TRIAL AFTER 2 YEARS OF EXPERIMENTS

Accession Number	Variety	Source	Yield (Pounds per Acre*)	Remarks
<i>Yields Based on the Average of Tests 1 and 2 Plants Spaced Every 4 Feet in Rows 6 Feet Apart</i>				
19	35-CS20b-12-F11	W. S. Porte, Florida, United States Department Agriculture	20,401	
38	5-1-1	J. C. Miller, Louisiana Agricultural Experiment Station	19,711	Louisiana Pink X Break O'Day
15	35-CS14b-F7	W. S. Porte, Florida, United States Department Agriculture	19,529	
13	35-CS12b-F7		19,402	
7	35-B17a-2-F6		18,767	
8	35-H9-6-F16		18,295	
45	Grothen's Globe	Ferry-Morse Seed Company	17,152	Selection from Break O'Day
30	Break O'Day	W. S. Porte, Florida, United States Department Agriculture	16,680	
32	Pritchard	Ferry-Morse Seed Company	16,662	
47	Pritchard		14,865	
<i>Yields Based on Test 4. Plants Spaced Every 2 Feet in Rows 6 Feet Apart</i>				
410	Break O'Day 2671 2	M. Takahashi, Hawaii Agricultural Experiment Station	18,549	
408	New Stone 2670.3	W. K. Bailey, Puerto Rico Agricultural Experiment Station	16,262	
301	Marglobe X Native Puerto Rican		13,322	
306	Puerto Rico tomato Type 5—fruit 5		12,161	A commercial-type has been selected from this accession

\*Yield figures represent the combined weight of No. 1 and No. 2 fruit.

Break O'Day and Pritchard are the two most widely planted varieties in Hawaii, but the results of these investigations indicate that certain unnamed introductions from Florida and Louisiana were superior to these varieties at Waipahu.

## CONCLUSIONS

The superiority in Hawaii of many strains of tomatoes developed by plant breeders in the southern continental United States is striking. Standard commercial varieties grown in the Territory have not proved so vigorous or so productive, and they are often equalled or surpassed in market quality by these introduced strains.

## ACKNOWLEDGMENTS

The writer is greatly indebted to Mr. W. S. Porte of the United States Department of Agriculture, Dr. J. C. Miller of the Louisiana Agricultural Experiment Station, and others who furnished seed of their promising tomato strains, as well as to the Oahu Sugar Company, Ltd. for land, labor, and other facilities for conducting the experiments. Credit is due Miss Ah Sin Char, who performed most of the calculations, and S. Tachibana for invaluable aid in the field.

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# Copper Content of Some New Jersey Grown Tomatoes<sup>1</sup>

By ALBERT L. WEBER and HARRY C. McLEAN, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

ALTHOUGH the original interest on the subject of copper in foods was due to the findings of University of Wisconsin workers (5) a decade ago, that copper is a supplement to iron for hemaglobin building in the rat, the present viewpoint, especially the British, is that there should not be too great a quantity of copper in foods, especially tomatoes (1). Lindlow, Elvehjem and Peterson (4) reported the copper content of 158 foodstuffs. They report from 0.1 parts per million of copper in fresh celery to 44.1 parts per million in fresh calf liver and 9.9 parts per million of copper in tomatoes. Elvehjem and Hart (2) in reporting the copper content of feeding stuffs, found a range of from 2 parts per million in straws to 89.5 parts per million of copper in gluten feed and state that they believe the high copper content of certain feeding stuffs results from contamination during their manufacture. They also show that by adding copper sulphate to the soil they can increase the copper content of plants grown upon such soils.

Cockburn and Herd (1) found in fresh tomato juice 2.5 parts per million of copper, which is equivalent to 45.0 parts per million on the dry weight basis. They also found that many tomato purees on the market contain much more copper. They state that increase of copper in the purees was due to unavoidable contamination from the utensils used in processing.

Kollyar, Oikhlman and Shnaidman (3) found no increase in copper by immersing copper plates in hot tomato juice of .66 per cent acidity and in tomato juice acidified to 2 per cent acid (pH 4.2 to 3.1) with organic acids and boiled for 1 to 8 hours with brief admission of air during the boiling. Plates coated with an oxide film before immersing in the above solution greatly increased the solution of copper. When the juice is processed alternately through iron pipes first, then copper pipes, the iron dissolved in the juice increased the destructiveness to the copper plate ten fold.

The present work was conducted to determine the natural copper content of New Jersey grown tomatoes.

## MATERIALS AND METHODS

In determining the copper content of the tomatoes or products the following procedures were used: In case of fresh tomatoes either ripe or green, enough whole tomatoes were taken to make a sample of 700 to 800 grams and washed thoroughly with cold water. These were sliced and dried first on a steam bath and then in an oven at 100 degrees C. The whole sample was then ashed in a muffle furnace at 500 degrees C. In the case of the canned tomato products, the sample

<sup>1</sup>Journal Series paper of the New Jersey Agricultural Experiment Station, department of spray residue investigations.

taken was just large enough so that a 50 per cent aliquot would contain approximately 1/10 milligram of copper.

The actual method used was the carbamate method (using sodium diethylthiocarbamate) as suggested by and recommended by Mr. C. A. Greenleaf of the National Cannery Association, Washington, D. C. He states that of four different methods tried in the laboratory, the above appeals to him as reliable and convenient. Briefly, the method is as follows: The sample is ashed at 500 degrees C, the ash is dissolved in 1 + 1 HCl filtered and washed (when necessary using a sulphide separation). The filtrate or aliquot is made alkaline to litmus with ammonium hydroxide. To the ammoniacal filtrate is added the carbamate solution and the resulting copper carbamate is extracted with iso-amyl alcohol. The unknown is compared in a colorimeter with a standard made from copper sulphate treated similar to the unknown.

It was found that tomatoes and tomato products at 500 degrees C ash with great difficulty. As it is necessary to ash completely to be able to determine the exact copper content, the above method was modified slightly in that when the tomatoes were only partially ashed to a black char, they were extracted with HCl, washed with small amounts of hot water, the residue dried and re-ashed and the ash taken up with the original filtrate. This modification was found to save much time and ashing was complete.

## RESULTS

In the following table are given the ripeness of the tomatoes, type and pH of the soil that the tomatoes were grown on, and the copper content of the tomatoes calculated on the dry weight basis.

TABLE I

Farm	Condition	Copper Dry Wt. Basis (Ppm)	Type of Soil	pH of Soil
1.....	Red ripe	22.3	Sassafras	6.15 to 6.6
	Yellow ripe	17.3	Sandy loam	
	Green	14.2		
2.....	Red ripe	16.2	Sassafras	6.1 to 6.6
	Red ripe peeled	13.6	Sandy loam	
	Green	10.0		
3.....	Red ripe	24.0	Sassafras	5.8 to 6.2
	Red ripe peeled	18.0	Sand	
	Red ripe	12.6	Sassafras	
4.....	Green	9.8	Loam	6.2 to 6.6
	Red ripe	16.3	Sassafras	
	Yellow ripe	16.0	Loamy	
5.....	Green	14.5	Sand	5.8 to 6.4
	Red ripe	12.0	Sassafras	
	Yellow ripe	11.0	Loamy sand	
7.....	Red ripe	22.0	Sassafras coarse Sand	5.0 to 5.4

Only one of these samples, from Farm 3, received copper sprays. In this instance two copper sprays were applied when the tomatoes were relatively small. This sample was divided into two lots one of which was peeled. From the analyses of samples from Farms 2 and 3, peeled and unpeeled, it can be seen that most of the copper on sample from Farm 3 due to sprays had been weathered off at the time of harvest. It should be pointed out that the coarser the physical condition

of the soil, the higher the copper content, and to a more or less degree the lower the pH the higher the copper content of the tomatoes. It also should be noted that as the tomatoes became riper there was a progressive increase in the copper content.

A cursory survey of several canned tomato products show in the main that the canning of whole tomatoes does not increase the copper content and in the production of tomato juice there may or may not be an increase of copper, depending upon the type of utensils used. As for the samples of puree analyzed, there was always an increase of copper, certain samples containing as high as 77 parts per million. One lot of tomato juice was packed in lacquered cans. This lot contained 64.0 parts per million of copper while puree from the same cannery packed in unlacquered cans contained 46.0 parts per million of copper calculated on the dry weight basis. This indicates that there is a tendency of the copper in the tomato products to plate out on the inner side of the unlacquered can.

It was noted that all samples of ketchup analyzed were relatively low in copper as compared with juice or puree, figured either on the dry weight basis or on the product as packed.

### CONCLUSION

It was found upon analysis of a limited number of samples of New Jersey grown tomatoes that they contained naturally 9.8 to 22.3 parts per million of copper on the dry weight basis, depending upon the ripeness of the tomato and the type and pH of the soil upon which they were grown. A few analyses of processed tomato products are given.

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# Response of Tomato (*Lycopersicum esculentum*, Mill. var. Marglobe) to Certain Vernalization Treatments

By H. L. STIER, *University of Maryland, College Park, Md.*

**P**RESENT vernalization technique has been most successful in accelerating reproduction in cereal crops, especially wheat and rye. Attempts have been made by a number of workers (1, 3, 4, 8) to promote earlier flowering and fruiting in certain of the vegetable crops by some type of vernalization treatments. Relatively few of the efforts have been successful. Using the Lysenko technique, McMillan, Christian and Hills (4) report that there was no significant difference in either the time of maturity or in the yield between tomato plants from seeds that were vernalized and tomato plants from seed that were untreated. Burr and Turner (1) working in England with tomato, placed moist seed of the variety Ailsa Craig at 1 to 3 degrees C for 5, 16, 32, and 44 days. They report that germination was reduced in proportion to the length of the cold storage period, and that the plants from treated seed lagged behind the controls in growth, fruit setting, time of fruit ripening, and yield of fruit. Of the four periods of cold storage they state that the plants from the seed treated 44 days were most vigorous. In a later experiment with tomatoes, Turner and Burr (8) report considerable decrease in the time required by the plants for flower and fruit production, as the result of the vernalization treatments. They report that plants from seeds prechilled for 24 days at a constant temperature of 31.5 degrees F and the seedlings given continuous light for 12 days produced the first flowers and fruit (first picking) 27 days earlier than the check plants.

Such acceleration in growth and development of the tomato plant is both of scientific as well as of possible economic importance. The experiment reported in this paper was carried out for the purpose of determining the most effective combination of vernalization treatments for causing early flowering and fruiting of the Marglobe variety of tomato under both field and greenhouse conditions in Maryland. The treatment combinations were so planned that it was possible to determine whether the photoperiod of the seedlings or the temperature at which the moist seeds were stored, alone or combined, was the effective agent in producing the accelerating effect.

## MATERIALS AND METHODS

In both the greenhouse and the field experiment Master Marglobe was the variety grown. The plants in the greenhouse experiment were grown in 2-gallon, glazed coffee liners in quartz sand which was supplied with Shive's four salt solution by the drip method (6). The greenhouse plants were pruned to a single stem and topped one node after the fifth cluster was formed. The plants were arranged in a

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Scientific Contribution No. 490, Department of Horticulture, Maryland Agricultural Experiment Station.

modified Latin square so that the effect of the position in the greenhouse could be determined by the analysis of variance. Each treatment was represented by four different plants each located in a different position in the house. The greenhouse plants were grown during the winter and spring months from January 1 until June 14, 1938. In the field plots the plants were grown in *Sassafras* fine sandy loam soil, each treatment was planted in duplicate in single row plots of 20 plants each. The plants were transplanted to the field on May 18, 1938.

For cold temperature vernalization of the moist seeds three periods were used; 15, 30, and 45 days, during which the temperatures fluctuated between 32 and 35 degrees F. One-half gram of air dry seeds were used for each treatment. Each lot of seeds was placed in a separate petri dish on three sheets of filter paper and 5 milliliters of water added to the seeds before the cold storage treatment began. The pretreatment of the seeds consisted of allowing the seeds to remain at laboratory temperature (78 degrees F) for either 1, 2, or 3 days after they were moistened and before placing them at the low temperature. One lot of dry seeds in a petri dish was placed in the low temperature room at the time each of the three low temperature treatments of moist seed were started. The time of starting the various treatments was so arranged that all seeds were removed from the cold storage on the same date and planted immediately. When the seeds were removed from the low temperature room all were planted in quartz sand which was kept moist by use of tap water and periodic application of a complete nutrient solution. When the seedlings began to emerge half of each lot were immediately placed under continuous photoperiod for 30 days while the other half were allowed to develop in the normal photoperiod for that particular season of the year (9 to 10 hours). The light sources of the artificial illumination at night were 200 watt Mazda bulbs in 18 inch white enameled reflectors spaced 6 feet apart and suspended approximately 30 inches above the tips of the seedlings. The plants in the greenhouse experiment were transplanted to the glazed coffee liners at the end of the photoperiod treatment while those grown for the field experiment were planted in the field 7 weeks after seeding.

#### EFFECT OF THE VARIOUS VERNALIZATION TREATMENTS

*Average Number of Leaves per Plant at Transplanting:*—Data for this item were obtained only for the greenhouse crop. From Table I it is evident that the continuous photoperiod caused the production of a slightly greater number of leaves on the plants in a given time, in the 15 and 30 day low temperature seed treatments. In the 45 day series it appears that the longer cold temperature treatment of the seed tended to counteract the effect of the additional photoperiod in the production of a greater photosynthetic area. The average number of leaves produced by the plants shows a trend towards an increase in the number of leaves formed per unit of time as the length of the period of low temperature storage of the seeds increased.

*Time of Anthesis of the First Blossom:*—In the greenhouse there was on the average 10 to 12 days earlier flowering of the plants under

TABLE I—EFFECT OF VERNALIZATION TREATMENTS UPON GROWTH AND FRUITING OF TOMATO PLANTS  
(GREENHOUSE AND FIELD, 1938)

			Greenhouse				Field		
Number Days Moist Seed Stored at 32 to 35 Degrees F	Number Days Moist Seed Remained at 73 Degrees F Before Low Temperature Storage	Daily Photo- period of Seedlings During First 30 Days	Number Leaves per Plant (February 25)	Anthesis of First Blossom*	Yield of Ripe Fruit		Average Date Anthesis of First Blossom**	Early Yield Fruit (Pounds) (July 19 to August 12)	Total Yields of Fruit
					Grams	Per Cent Total by Weight			
15	0	Normal†	7	15	2450	92.6	18	384.6	668.0
15	1	Continuous	7	11	4890	98.0	23	193.4	396.3
15	1	Normal	4	22	4025	89.1	18	234.0	451.7
15	1	Continuous	5	8	3575	100.0	16	199.6	335.4
15	2	Normal	7	16	2845	96.3	17	274.1	434.9
15	2	Continuous	9	8	3300	95.0	17	113.4	368.7
15	3	Normal	5	23	3010	85.5	17	182.1	263.7
15	3	Continuous	7	10	3845	97.0	21	335.1	642.0
30	0	Normal	6	14.1	3492.5	93.4	18.6	248.1	445.1
30	0	Continuous	6	14	3990	86.1	18	229.4	391.7
30	1	Normal	6	12	3390	93.3	21	734.5	734.5
30	1	Continuous	5	16	4295	86.9	17	269.5	408.5
30	2	Normal	9	10	4590	88.4	20	392.8	725.9
30	2	Continuous	6	15	5080	85.1	20	326.8	532.1
30	3	Normal	7	7	3435	97.0	18	331.2	582.4
30	3	Continuous	4	22	3355	74.0	20	421.8	709.7
30	3	Continuous	9	5	3680	96.2	20	233.9	400.4
45	0	Normal	6.5	12.6	3974.4	88.4	19.2	321.2	486.9
45	0	Continuous	4	19	3775	92.8	18	341.7	559.1
45	1	Normal	7	13	2760	98.1	24	219.8	461.8
45	1	Continuous	9	5	4720	96.0	19	365.1	708.4
45	2	Normal	8	8	4945	99.3	21	195.8	382.0
45	2	Continuous	6	9	3360	99.4	22	288.1	509.2
45	3	Normal	6	10	4875	87.1	19	297.1	583.5
45	3	Continuous	7	11	5485	92.9	18	209.7	344.7
45	3	Continuous	7	10	3865	87.6	19	283.2	506.2
0	0	Normal	6.75	10.6	4198.1	94.1	20.0	275.1	508.6
0	0	Continuous	6	12	3805	96.2	—	—	—
0	0	Continuous	7	7	4920	99.5	—	—	—
Significant Difference	5 per cent level		2	5.1	1647.0	10.1	2.66	92.5	119.6
	1 per cent level		3	7.6	2470.5	15.2	3.86	138.8	179.4

\*The numbers in this column represent the number of days after March 18, 1938.

\*\*The numbers in this column represent the number of days after May 25, 1938.

†Normal photo-period for the greenhouse crop during this time was 9 to 10 hours and for the field crop 12 hours.



continuous light (when compared to those under normal) in the 15 and 30 day low temperature seed treatments. However, in the 45 day series there is no significant difference in the date of anthesis of the first blossom on plants in the normal photoperiod and plants in the continuous photoperiod series. The greatest difference in the time of blooming of the plants in the two photoperiod treatments is evident in the 15 day low temperature seed treatment. The difference decreases in the 30 day series and entirely disappears in the 45 day series. This indicates the accumulative effect of the increased time of low temperature treatment of the seeds. After 45 days of storage of the moist seeds, at the near freezing temperature, the plants bloomed as early under normal length of photoperiod as plants in this, or any other lot, under continuous light. The earliest blooming was obtained from the combination of 30 days cold temperature storage of the seeds and continuous light for the seedling for 30 days after germination. Analysis of variance of the date of anthesis of the first blossom on plants in the various treatments showed that under greenhouse conditions both the length of the low temperature storage of the moistened seeds and the length of the photoperiod to which the seedlings were exposed caused a highly significant effect upon the date of anthesis of the first blossom. The length of presoaking the seeds before placing at the low temperature also caused a significant difference in the date of anthesis of the first blossom. Examination of the averages for the three periods of the seed pretreatment showed that there was no difference between 1 and 2 days pretreatment but when 3 days elapsed between moistening and low temperature storage the average date of anthesis of the first blossom on all the treatments was about 3 days later when compared to the value for the other periods. This indicates that approximately 2 days is probably the optimum length of time to allow the seeds to imbibe water and start the germination processes before beginning the low temperature storage of the seeds. When the anthesis date of first blossom for the plants from the seeds which were stored in a dry condition in the cold room are compared with those for the moist seeds it is seen that all of the low temperature vernalization treatments of the seed caused some degree of acceleration in the anthesis of the first blossom. The effect of the two photoperiods is also evident in the values for the dry seeds.

Comparison of the average dates of anthesis of the first blossom for the different seed vernalization treatments showed little difference between plants in any of the treatments under field conditions. However, analysis of variance of the data showed that when the variability within and between treatments was considered the 15 day cold storage period of the seeds caused significantly earlier flowering than the 30 or the 45 day treatments.

Comparison of the averages for the two photoperiod treatments of the seedlings indicated that instead of the continuous photoperiod having an accelerating effect upon time of flowering, as it appeared to have under greenhouse conditions, there was actually a slight retarding effect. Analysis of variance gave a highly significant F value for the variance between photoperiods. When the average date of anthesis of

the first blossom on plants from the dry seeds is compared to the average for the plants from the various vernalization treatments, it is found that the difference between the 15 day treatment and the controls is significant. The 15 day cold storage of the moist seeds caused earlier flowering than was obtained on the control plants. However, the 30 and the 45 day periods did not show any difference when compared to the check plants.

*Early and Total Yield of Fruit:*—Under greenhouse conditions it appears that the longest period of low temperature treatment of the seeds (45 days) resulted in earlier fruit production than did any of the other treatments. This can be seen in Table I from the number of fruit harvested from the plants expressed as per cent of the total number of fruit produced by the plants. There was no difference in the *total* yield of plants in the various series of low temperature seed treatments. However, there was an evident tendency for the plants from seeds given the longer cold storage treatments to yield more than plants from the shortest period (15 days). This is probably only another expression of the earlier maturity of the fruits on these plants. Analysis of variance of the yield of the plants in the greenhouse crop showed a significant F value only in the second order interaction; vernalization periods x photoperiods x seed pretreatments.

Under field conditions the individual treatment that produced the greatest early yield of fruit was that where the seeds had been stored at the low temperature for 30 days, soaked at 78 degrees F 3 days before placing at the low temperature and the seedlings given the normal length of photoperiod prevalent at that time of the year (12 hours). When the total yield of the plants in the field experiment is considered, it is evident from the yields presented in Table I that none of the treatments caused a significant difference over the yield of the check plants.

Comparison of the average values for days from blossom anthesis to fruit maturity showed that there was no difference in the rate at which the fruits developed on the plants in the various vernalization treatments. Fruits on plants in all treatments required an average of 55 days from blossom anthesis to maturity in the greenhouse. Any effect which the treatments had upon hastening the time of fruit maturity was the result of the treatment causing earlier flowering and not caused by any effect which caused the fruit to develop more rapidly.

## DISCUSSION

Under greenhouse conditions certain of the vernalization treatments caused a definite acceleration in plant growth and development. Although the difference between date of anthesis of the first blossom on plants in the most effective vernalization treatments and anthesis date on control plants is highly significant statistically, it amounts to only about 7 to 8 days. This is about 20 days less than the difference obtained by Turner and Burr (8) from their most effective treatment. Total yield was not materially altered by the various treatments. The same treatments caused quite different response in the plants when

they were grown under field conditions in the summer. Instead of the additional photoperiod having an accelerating effect on flower and fruit production it appears under field conditions to have had an inhibiting effect. Recently Purvis and Gregory (5) have demonstrated the relationship of the photoperiod at which the plants are subsequently grown and the response to the low temperature seed vernalization treatments. On the basis of their work the results obtained in this experiment under the field and greenhouse conditions can be attributed to the effect of the difference in the length of the photoperiod under which the plants were grown for the major portion of their vegetative and fruiting life. Under the greenhouse conditions the plants in the effective treatments were exposed to a long day (continuous light) for a period of 30 days after which the plants were permitted to develop for the remainder of their greenhouse life under the normal photoperiod for that season of the year, which was about 10 hours of sunlight. Under the field conditions the plants were taken from the continuous photoperiod and placed in a photoperiod of 14 to 16 hours. Another factor that probably played an important part in the difference in response of the plants grown in the greenhouse and the field was the difference between the intensity of the light under the greenhouse conditions as compared to that present when the plants were growing in the field. It may have been that because of the longer photoperiod and the greater light intensity under which the plants were grown in the field that the vernalization treatments were not effective in accelerating flowering or fruiting of the plants. The long days of the summer and the high light intensity may have resulted in such a high degree of plant efficiency in the field that any accelerating effect the vernalization treatments might have induced during the seedling stage was obliterated. Since the efficiency of the plants was of necessity low during the winter months of the year in the greenhouse, the vernalization treatments could more readily affect growth and development of the plants. Also, the combination of long days during the early development of the plants followed by short days later may have been a more optimum combination for permitting expression of the effect of the cold temperature seed treatments.

#### SUMMARY AND CONCLUSIONS

Three different periods of low temperature vernalization of tomato seeds were used; 15, 30, and 45 days. Before placing the seeds in low temperature storage they were allowed to imbibe water and start germination processes for 1, 2 or 3 days. Each of the lots in the low temperature treatments were further subdivided into two lots, in one lot the seedlings were given continuous light for 30 days and in the other lot they were exposed only to the normal length of day. The results reported are those secured from a greenhouse experiment and from a field experiment, the same treatments being used in each case. The response to the vernalization treatments under the field conditions was very slight and of no practical importance under the greenhouse conditions.

Certain of the vernalization treatments caused 10 to 14 days earlier

flowering of the plants, there being an evident tendency for the time of anthesis of the first blossom to be earlier as the length of the low temperature period became longer. In the 15 and 30 day treatments the effect of the continuous photoperiod in speeding up the flower development of the plants was quite evident, but in the 45 day treatment the effect of the long photoperiod in this respect was nil having been apparently counterbalanced by the accelerating effect of the additional 15 days low temperature treatment of the seeds. The vernalization treatments exerted no effect upon average number of leaves formed by the plants per unit of time nor upon the rate of fruit development or the total yield of the plants.

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# Soil Acidity for Greenhouse Lettuce and Tomatoes

By JOHN D. HARTMAN and EDWARD C. STAIR, *Purdue University, Lafayette, Ind.*

**I**N all or nearly all of the many vegetable greenhouses in the vicinity of Indianapolis soil acidities range between pH 7.0 and 8.2. The principal crops are leaf lettuce and tomatoes grown in rotation. The usual program calls for a crop of lettuce in the fall, lettuce again in the winter and early spring, and tomatoes in the spring and early summer. Almost invariably the careful growers have good crops, but since on some soils increasing alkalinity above pH 7.0 or 7.5 decreases yields, especially of lettuce, it seemed possible that better and more vigorous plants might be grown if the soil were made more acid. To test this possibility an experiment was laid out in the Purdue University greenhouses.

## MATERIALS AND METHODS

Plots, 16 by 5.6 feet, were laid out on a ground bed. These were divided into blocks of four each. Four treatments were compared in quadruplicate. These treatments were as follows:

1. Control. No acidifying agent added.
2. Aluminum sulfate. Aluminum sulfate added at rate of 10,000 pounds per acre on August 15, 1937.
3. Low Sulfur. Sulfur and sulfuric acid added at rate equivalent to 1,600 pounds of sulfur per acre on August 15, 1937 and again on January 4, 1938 at the rate equivalent to 1,200 pounds of sulfur per acre.
4. High sulfur. Same as 3, but rates equivalent to 3,600 pounds of sulfur on August 15 and to 2,400 pounds of sulfur on January 4.

For the second application on treatments 3 and 4, only sulfuric acid was used, but at the first application 400 pounds of the sulfur for treatment 3 and 1,200 for treatment 4 was elemental. The crude aluminum sulfate used contained about 14 per cent sulfur. So the application of sulfur for treatment 2 was at the rate of 1,400 pounds per acre. These materials were scattered on top of the soil and, soon afterwards, mixed with it when it was spaded.

At the time of the first application of soil amendments acid muck (pH 4.6) and peat (pH 3.5) were added to all plots for the purpose of improving the physical condition of the soil. Rates of applications of these materials were about 90,000 and 16,500 pounds per acre, respectively.

One crop of Grand Rapids lettuce was harvested from these plots on November 15 and 22, 1937 and another on March 10 to 17, 1938. Tomatoes of the variety Long Calyx (Huelson) were grown on them from March 21 to August 3, 1938. All plots of a single block of replicates were, of course, harvested on the same date. Records were taken only on the central parts of each plot. The border areas on which no records were taken were 2.8 feet wide. They were planted in the same

manner as were the portions used in the test. In the case of the tomatoes, there was one row of plants along the median line through each plot, and one on each dividing line between plots.

The only fertilizer added during the year was sulfate of ammonia, at the rate of 250 pounds per acre, to the tomatoes. This nitrogen was applied on April 2, 1938, at a time when a good many of the plants had become slightly yellowish green.

The soil, even before the peat and muck were added, was high in organic matter. It was porous enough that water did not run on the surface during waterings.

Soil samples were taken on all plots at the beginning of the experiment and after each crop had been harvested. The active acidity of all these was measured. Those taken in November, 1937, and March, 1938, when differences in acidity among plots were greatest, were also tested for nitrate nitrogen, ammonia nitrogen, phosphate phosphorus, potassium, calcium, magnesium, manganese, aluminum, and sulfate sulfur. These tests were made on soil extracts with very weak (0.1 per cent) acetic acid. Rapid methods were used, but all comparisons were made against permanent color or turbidity standards in artificial light. Outlines of the procedures for determining the primary elements are given in a previous publication (6), but for potassium tests reagents were stored at 34 to 36 degrees F and portions of extracts cooled to this temperature before being mixed. The hematein test was used for aluminum. The sample of hematein used gave no color with ferric iron. Tests for other elements were adaptations of those of Spurway (8).

All soil samples were tested together at the end of the experiment in a succession determined mainly by chance. At the time of testing the identity of the sample was known only by number. Rapid tests do not give such clear-cut indications of quantity, especially where turbidities are involved, that one may allow his judgment to be biased by unnecessary knowledge.

## RESULTS

Yields of lettuce were fairly good and of tomatoes remarkably good. Averages and differences necessary for significance are given in Table I. When the first lettuce was set, there were an insufficient number of the plants intended for the bed. Unfortunately, then, certain plots and parts of plots were set with smaller plants. When this was discovered, it was decided that these later plots should be discarded. Consequently, only two blocks of replicates were complete in this first harvest.

The soil and the plants used were evidently more uniform than is usually the case in field experiments. There was practically no variance due to block. Evidently having the plots extend lengthwise from the central walk to the side of the house overcame most of the effects of differences in lighting, ventilation, and watering so often found in different parts of greenhouses.

On August 13, 1937 the average pH values of the plots were 7.8, 7.7, 7.8, and 7.8 for treatments 1 to 4 respectively. On August 16, after the acid muck and peat were incorporated with the soil the pH of the check plots had dropped significantly to 6.7. Plots of other treatments would have been equally acid if only muck and peat had been

TABLE I—EFFECTS OF GREENHOUSE SOIL ACIDITY ON YIELDS OF MARKETABLE LETTUCE AND TOMATOES\*

Treatment	Yields of Lettuce						Dry Matter** in Winter Crop of Lettuce (Per Cent)	Yields of Tomatoes	
	Fall Crop				Winter Crop				
	2 Replicates		4 Replicates						
	(Pounds per 100 Square Feet)	(Tons per Acre)	(Pounds per 100 Square Feet)	(Tons per Acre)	(Pounds per 100 Square Feet)	(Tons per Acre)		(Pounds per 100 Square Feet)	(Tons per Acre)
Check	63	13.8	—	—	56	12.1	3.2	259	56
Aluminum sulfate.	64	14.0	60	13.0	58	12.6	3.3	257	56
Low sulfur	69	14.9	69	15.0	55	11.9	3.6	243	53
High sulfur.	60	13.0	—	—	47	10.1	3.5	239	52
Difference necessary for significance	N.S.†	N.S.†	N.S.†	N.S.†	5	12	N.S.†	8	2

\*Crops were grown and tomato records taken by Mr. F. Winters.

\*\*Samples taken between 7 and 9 a.m. and dried at 90 degrees C.

†No significant difference, as indicated by Fisher's z test

added. Soil test results, including pH values, for March and November, are shown in Table II. By August 3, 1938, when the experiment was terminated, all plots had become more alkaline than they were in November and March. The active acidities were pH 7.7 for the checks, 7.4 for the aluminum sulfate plots, 7.1 for low sulfur, and 6.6 for high sulfur. Differences obtained in all possible comparisons between these figures are significant.

TABLE II—SOIL TEST RESULTS AT TWO DATES OF SAMPLING

Treatment	pH	Ni- trate N	Am- monia N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Ca	Mg	Mn	Sul- fate S
November 15 or 22, 1937									
Check	7.4	85	18	548	375	725	625	1.9	140
Aluminum sulfate	6.9	71	20	302	360	1935	1135	3.1	585
Low sulfur	6.7	68	20	570	285	1625	950	2.6	500
High sulfur	6.1	55	23	686	390	1810	1725	5.8	1310
Difference necessary for significance	.5	N.S.	N.S.	116	N.S.	515	510	2.3	695
March 14 or 19, 1938									
Check	7.3	56	24	332	270	910	685	1.9	260
Aluminum sulfate	7.2	25	25	216	264	1625	1150	2.9	585
Low sulfur	6.6	34	33	572	308	2000	1525	5.1	1355
High sulfur	5.9	23	41	584	323	2125	2360	10.5	2455
Difference necessary for significance	3	N.S.	N.S.	115	N.S.	240	520	1.5	970

Most of the soil samples were taken to a depth of 8 inches, but on August 3 several samples were taken at a depth of 8 to 16 inches in one plot of each treatment. Tomato roots penetrated to the 16- or 17-inch level, the level of the centers of the tile drains, but no deeper. This lower soil was almost identical in appearance with the upper soil, but the soil below the 17-inch level was clay. Tests showed this soil at the 8- to 17-inch level to be slightly alkaline, and apparently not much affected by the treatment of the soil above. So, after the tomato plants, and perhaps the lettuce also, had become well established, they could draw nutrients from alkaline soil regardless of the acidity of the

surface. But, if the plants had really benefited from having the soil acidified, they would have drawn from the surface soil ample amounts of the nutrients made more available by the acidification. The growth of young plants on the soil, except of the lettuce plants of the first crop, showed no apparent differences among plots. Radishes seeded in the soil between the two crops of lettuce, germinated and grew to remarkably nearly the same size on all plots before they were removed. The first crop of lettuce, set immediately after concentrated sulfuric acid had been added, appeared to be stunted slightly, at the beginning, on two of the high sulfur plots.

As shown in Table II, the sulfate test had the greatest absolute and percentage inaccuracy. The standards used for this test were not very satisfactory. The relative amounts of sulfur indicated are, of course, correct within the limits indicated by the differences necessary for significance.

No aluminum, at least not more than 0.5 pound per acre, was extracted from any sample at either date.

### DISCUSSION

As shown in Table I, a slight decrease in yield resulted from the use of large amounts of sulfur. Better growth was obtained at the higher pHs. This result is in accord with the findings of Emmert (3) in Kentucky. The results on lettuce are not in agreement with those of Hardenburg (4), who used muck from the Kankakee region of Indiana, and decidedly not in agreement with those of Crist (1) in Michigan.

It seems quite possible that this difference in results with different soils is due largely to their different manganese content. The soil in this experiment may be considered very high in manganese, since with this very weak extracting solution it gave a positive test for manganese at any pH. The senior author (7) found that on Long Island usually no manganese could be extracted at any pH between 7.0 and 4.7 with this weak solution, even in cases where apparently no manganese deficiency existed.

Emmert emphasizes the abundance of available manganese at low pHs in the soil with which he worked. On the other hand, Ellis (2) has found that mucks from the Kankakee section of Indiana, such as Hardenburg used, usually show manganese deficiency above pH 7.0. According to the evidence of Harmer (5), Michigan mucks, one of which Crist used in much of his work, are frequently very low in available manganese, especially when alkaline.

It is conceivable that the deleterious effects of sulfur in the experiments reported here may, in fact, be due to the increase in manganese to a toxic concentration, but this seems unlikely. Emmert emphasizes the toxic properties of manganese.

Other essential elements, except nitrogen, appeared to be present in such abundance that the lowest availabilities found certainly did not indicate that growth would be limited at all by any of these elements. The increased amounts of ions extracted, where sulfur was added, tend to show, however, that an increase in the osmotic concentration, unfavorable to the most rapid growth, might have occurred.



Aluminum from the aluminum sulfate was effective in materially reducing the supply of easily soluble phosphates in the soil. It also is apparent that this soil did not contain an abundance of even slowly soluble aluminum or ferric iron. Otherwise the addition of sulfur would have brought these metals into solution temporarily and rendered more phosphates insoluble.

The solubility of calcium and magnesium were increased by the acidifying treatments. These elements are ordinarily extracted in greater abundance from a soil which has been alkaline for some time than from one which has been acid. However, the effects found in these experiments are in line with those reported by the senior author (7) and others in that they indicate that calcium and magnesium become more available temporarily when acidity is increased during the season.

The general level of all elements of the check plots in this experiment was very similar to that found in all the Indianapolis greenhouses where soil samples have been taken. Many of these soils of commercial greenhouses contained very easily extractable manganese, even at high pH levels, and nearly all gave strong tests for this element in extracts made with 0.3 per cent (by volume) HCl.

In all of them, easily available phosphates, calcium, magnesium, and potassium were abundant and easily soluble aluminum lacking.

The tendency of the soil to recover from acidity was partly due to the constant addition of very hard water, but also probably to the many particles of limestone in the soil. Estimates indicate that water was applied at the rate of about 855,000 gallons per acre during the course of the experiment. This water contained about 50 parts of magnesium and 60 parts of calcium per million. Hence, approximately 350 pounds of magnesium and 425 pounds of calcium were added. The natural acidity of this water is about pH 7.8. About .708 pounds of sulfur, as sulfuric acid, are required to acidify 1,000 gallons of it to about pH 6.0 and about .791 pounds to acidify it to pH 5.0. So, 600 pounds of sulfur per acre would be needed to hold the soil at pH 6.0 against the neutralizing effect of the water. About 680 pounds of sulfur would be required for the same purpose if a pH of 5.0 were to be maintained. The water used by Indianapolis growers is similarly hard.

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# The Absorption of Nutrients by the Tomato Plant at Different Stages of Growth

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A PROJECT was started to obtain information upon the time the nutrients are taken up by the tomato plant as well as the quantity absorbed. Starting with the transplants, samples of the plants were taken at monthly intervals for chemical analyses. The top growth of uniform plants from a Sassafras sandy loam were taken, the plants dried in an oven at 80 degrees C and ground in a Wiley mill. Since the composition of the plant is doubtless influenced by the available nutrients in the soil and the fertilizer applied, the character of the soil and the nutrients added are given in Table I. The fertilizer was supplied in three applications, one-third before planting and the remainder within the first 2 months after transplanting. The dry weight of 3000 plants at the different stages of growth is given in Table II.

## PERCENTAGE COMPOSITION OF THE MATERIALS

The most outstanding change noticed in the percentage composition as shown in Table III is the difference in the amount of calcium in the seed and that in the seedlings at transplanting time. The seeds contained 0.28 per cent calcium oxide while the young seedlings carried 4.59 per cent. This means that a large supply of readily available calcium must be available to the young seedlings for them to make this great change. A further indication that the seed were low in calcium is afforded by the low content of calcium in the fruit on the 2 and 3 months old plants.

TABLE I—THE SOIL CHARACTERISTICS OF A SASSAFRAS SANDY LOAM

	pH Value	Organic Matter (Per Cent)	Calcium	Mag- nesium	Alum- inum	Phos- phorus	Potash	Nitro- gen
Topsoil . . . . .	6.1	1.9	Good	Good	None	Very Good	Fair	—
Subsoil . . . . .	5.9	0.8	Fair	Good	None	Poor	Poor	—
Pounds per acre added as fertilizer . .	—	—	160	40	None	80	130	80

\*Method of analyses given in Bulletin 95, Virginia Truck Experiment Station.

A rather large change in the magnesium content of the seeds and the plant was noticed but next to calcium the largest change was in the potash content. It might be further pointed out that the fruit was high in nitrogen and potash but proportionately low in calcium and magnesium.

## ABSORPTION AT DIFFERENT STAGES

The results in Fig. 1 show the absorption of nutrients calculated for 3000 plants at different stages of growth. When the plants were set in the field they contained less than 1 pound each of calcium, mag-

nesium, nitrogen, phosphorus, and potash. Even at the end of the first month the quantities absorbed by the plants were very small as compared to those absorbed in the second and third months. In fact, the largest change occurred between the second and third months after transplanting. The nutrients absorbed in the largest quantities were potash, nitrogen, and calcium. However, the absorption of nutrients must not be confused with the application to the soil in order to get this absorption. While phosphorus is not needed by the plant in large quantities a large amount must be added to the soil because of the large amount fixed by the soil. This chart points out, however, that the plant nutrients are needed by the tomato in abundant quantities between the second and third months. If all of these nutrients are applied early, leaching and fixation is allowed to deplete the supply before the plant has had a chance to absorb any great amounts. Furthermore, the nutrients must be available in abundant quantities during a short period of time. These findings point to the fact that fertilization in two or three applications is wise. Specifically, a part is applied before the plants are set and a second and third portion at later dates. Perhaps the last application should be particularly high in nitrogen and potash.

#### THE TOMATO AS A SOIL BUILDING CROP

If a crop of tomatoes is adequately fertilized with nitrogen, phosphorus and potash and the vines and plant debris are plowed into the soil after the tomatoes are removed the soil is left in better condition than before the crop was planted. Take for example the crop considered in this experiment. Eighty pounds per acre of phosphorus ( $P_2O_5$ ) were added but only 14 pounds were removed by the fruit, 130 pounds of potash were added and 82 removed, 80

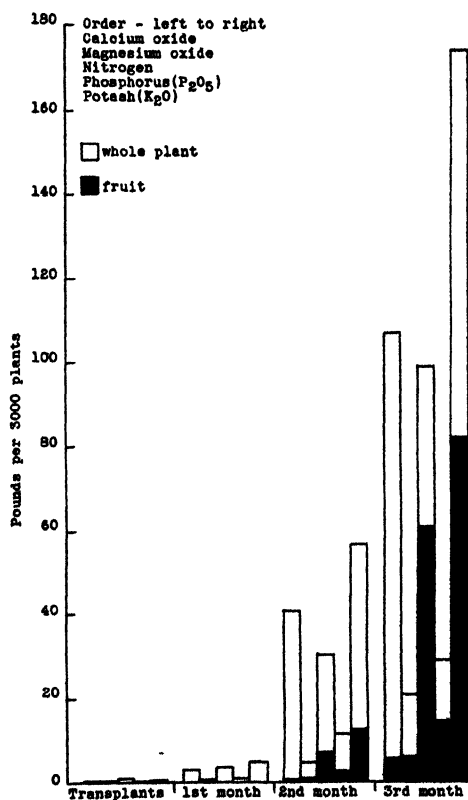


FIG. 1. The plant nutrients absorbed by tomato plants at various stages of growth.

TABLE II—THE WEIGHT OF 3000 PLANTS AT DIFFERENT STAGES  
(POUNDS OF OVEN DRY WEIGHT)

Seed	Transplants	1 Month Old	2 Months Old		3 Months Old	
			Vegetation	Fruit	Vegetation	Fruit
0.02	8.7	75.8	951.0	114.3	2100	1440

TABLE III—THE NUTRIENTS\* IN A TOMATO PLANT AT DIFFERENT STAGES

Nutrient†	Seed	Transplants	1 Month Old	2 Months Old		3 Months Old	
				Vegetation	Fruit	Vegetation	Fruit
Calcium (CaO) . . . . .	0.28	4.59	4.42	4.20	0.22	4.82	0.39
Magnesium (MgO) . . . . .	0.68	1.11	0.96	0.43	0.32	0.71	0.43
Nitrogen (N) . . . . .	6.93	7.31	4.62	2.52	2.80	1.82	4.20
Phosphorus (P <sub>2</sub> O <sub>5</sub> ) . . . . .	1.57	1.31	1.22	0.88	0.14	0.70	0.98
Potash (K <sub>2</sub> O) . . . . .	1.12	5.59	6.53	4.63	5.19	4.39	5.75
Iron (Fe) . . . . .	0.07	0.04	0.12	0.08	0.008	0.12	0.08
Manganese (Mn) . . . . .	0.016	0.015	0.014	0.023	0.033	0.010	0.041

\*Percentage composition on oven dry basis.

†Analyses by Official Methods.

pounds of nitrogen added and 60 removed, 160 pounds of calcium added and 6 removed, and so on. Furthermore, 1,500 pounds of oven dry organic matter was added to the soil not counting the root growth. From these figures it is evident that a soil planted to tomatoes and adequately fertilized should leave the soil in a state of fertility higher than that prevailing when it was planted. However, these calculations give no consideration to leaching of nutrients during the growth of the tomato crop and the soil must be protected from leaching and erosion by a cover crop or "catch crop" after the tomatoes have been harvested.

### CONCLUSION

Chemical analyses of tomato plants at monthly intervals show that a large portion of the nutrients were absorbed by the plant between the second and third months after transplanting in the field. This tends to substantiate the view that sidedressing at least with a greater portion of the nitrogen and potash after transplanting is a sound practice.

# The Influence of Certain Phytohormone Treatments on the Time of Flowering and Fruit Production of Tomato Plants Under Field Conditions<sup>1</sup>

By H. L. STIER and H. G. DUBUY, *University of Maryland, College Park, Md.*

IN most sections where tomatoes are grown commercially, any treatment which significantly shortens the time required by the plants to produce marketable fruit is of considerable practical value. During some seasons the production of early marketable fruit may mean the difference between profit and loss to the grower. The possibility of obtaining such acceleration in fruiting by means of the proper auxin treatments has been recently indicated. Cholodny (1) reported 55 per cent greater yield per plant when oat seed was soaked in a solution of B-indolylacetic acid before planting. Grace (2) has developed the dust method of treating seeds with phytohormones and from such treatments has reported an increase in dry weight of tops of month old wheat plants, grown in soil, as high as 20 to 30 per cent and in dry weight of the roots an increase amounting to as much as 65 per cent. He states that a number of varieties of garden seeds have also been tested and show similar response. Thimann and Lane (4) working with the Comet variety of tomato report that plants from seed swollen in auxin solution showed a hastening in the development of the photosynthetic area and three to seven days earlier flowering under greenhouse conditions.

In this paper is shown the effect of the phytohormone treatments upon the time of anthesis of the first blossoms and upon the early and total yield of the plants when grown to maturity under field conditions. The data presented are for only one season and are purely preliminary. Although the replication and arrangement of the plots in the field were not adequate to warrant broad generalizations and definite conclusions, some very definite responses and interactions are evident.

## MATERIALS AND METHODS

On April 1, 1938, 650 tomato seeds of Master Marglobe variety (Stokes, crop 1937) were divided into 13 lots of 50 seeds each. Twelve of these lots were treated with the respective phytohormone-talc mixtures listed in Table I.

The other lot of seed was not treated. Each of the 12 treated lots was placed in a glass vial with approximately 15 milligrams of the proper mixture and shaken vigorously until the seeds became uniformly covered with the dust. In every case practically all the mixture in the vial (15 milligrams) adhered to the seed coats. The seeds were germinated in quartz sand and grown according to standard practice until ready for field transplanting. Daily counts of germination were made and the coefficients of velocity of germination calculated according to the method of Kotowski (3). The plants were transplanted to

<sup>1</sup>Scientific contribution No. 489, Departments of Horticulture and Botany, Maryland Agricultural Experiment Station.

TABLE I—PHYTOHORMONE-TALC MIXTURES USED FOR TOMATO SEED TREATMENTS

Treatment Number	Acid in Mixture (Milligrams)	Talc in Mixture (Grams)
1	Napthylacetic 10	10
2	Napthylacetic 100	10
3	Napthylacetic 100	1
4	Indolyibutyric 10	10
5	Indolyibutyric 100	10
6	Indolyibutyric 100	1
7	Phenylacetic 10	10
8	Phenylacetic 100	10
9	Phenylacetic 100	1
10	Indolyacetic 10	10
11	Indolyacetic 100	10
12	Indolyacetic 100	1

the field on May 17. At this time the plants in each of the seed treated lots were separated into two portions of 10 plants each, the roots of one portion of each lot were dipped momentarily (2 seconds) into an aqueous solution of a-napthylacetic acid and the other portion into I-butyric acid solution in the same concentration. The plants were planted in two blocks in single row plots of 10 plants each, rows were spaced 6 feet apart and the plants were spaced 4 feet apart in the row. The soil was Sassafras fine sandy loam, the organic matter content of which was 0.5 per cent, and the level of nitrogen, medium; phosphorous, medium and potassium, low as shown by rapid chemical tests. The pH of the soil ranged between 5.0 and 5.5; rye was plowed under the latter part of March and 1,000 pounds of 6-6-5 fertilizer applied broadcast 2 weeks before planting. Cultivation was given frequently enough during the season to prevent the growth of weeds and side dressings of sodium nitrate were applied twice during the growing season (June 15 and July 20). The first blossom to open on the first three clusters of each plant was tagged the day it opened. The fruit was harvested when "red ripe" or "late pink" and graded and weighed immediately after picking.

## RESULTS AND DISCUSSION

*Effect of Treatments upon Percentage and Rate of Germination:*—The percentage of germination, and the coefficient of velocity of germination, for each of the seed treatments are given in Table II. There is no consistent or significant difference in the *percentage* of germination in the various treatments. However, there is a significant difference in the *rate* of germination between certain treatments. The difference in rate of germination is most marked in the different concentrations of napthylacetic acid, where it is obvious that the rate of germination decreased as concentration increased. This is clearly shown in Fig. 1. The odds are greater than 100:1 against the probability that these coefficients of velocity of germination for each of the three concentrations of napthylacetic acid (nos. 1, 2, 3) could have arisen by chance alone. Likewise, in the indolyibutyric acid series the low concentration (no. 4) caused more rapid germination. In the phenylacetic acid series the most rapid germination occurred in the high concentration (no. 9). The rate of germination of seeds in each of the three concentrations (nos. 10, 11, 12) of indolyacetic acid was the same. When compared



FIG. 1. Effect of phytohormone dust treatments of seeds upon growth of seedlings. Row No. from left to right corresponds to treatment numbers as listed in Table I. Note the definitely inhibitory effect of the high concentration of the naphthylacetic acid dust treatment (No. 3) photographed 15 days after planting seed.

to untreated seeds both the medium and the high concentrations of naphthylacetic acid (nos. 2, 3) caused significantly *slower* germination. The only treatment causing more rapid germination than that of untreated seeds was that in high concentration of phenylacetic acid (no. 9) and the difference is only significant at the 5 per cent level.

*Effect of Treatments on Time of Flowering:*—The average date of anthesis (expressed as days after planting) of the first blossom on plants in each treatment is given in Table II.

Using the 1 per cent level for determining the significance of the difference in blooming dates of the various treatments, it is found that plants from the low concentration naphthylacetic acid treated seeds (treatment 1) bloomed earlier than the plants from untreated seeds regardless of whether the transplants were dipped in indolylbutyric or naphthylacetic acid solution at the time of transplanting. At this level of significance (1 per cent) none of the other seed treatments caused earlier blooming in the indolylbutyric transplant treatment. However, in the naphthylacetic transplant treatment, when the 1 per cent level of significance is used, plants from seed treatments 1, 7, and 9 flowered earlier than the check plants; plants in these treatments flowered approximately 9 days earlier than the plants from untreated seeds. When the 5 per cent point is used as a level of significance the following seed treatments caused earlier flowering when compared to the checks: in the indolylbutyric transplant treatment, 1, 2, 5, 6, 9, 10, and 11; and in the naphthylacetic transplant treatment, 1, 5, 6, 7, 9, 10, and 11. The only treatments which were not consistent in producing earlier flowering in both transplant treatments were nos. 2 and 7. This indicates that there may have been an interaction between certain seed treatments and the transplant treatment used. Analysis of variance of the data revealed some interesting significant interactions. The pertinent values for the various main effects and their interactions are presented in Table III. These values indicate that: (a) the four acids used in the dust treatment of the seeds were *all* capable of causing earlier flowering as shown by the non-significant "F" value obtained for auxins in seed treatments. (b) The three concentrations of the auxins used in the dust seed treatments caused a differential effect upon time of blooming,

TABLE II—EFFECT OF PHYTOHORMONE TREATMENT OF TOMATO SEEDS AND PLANTS UPON GERMINATION, TIME OF FLOWERING AND YIELD; AND THE INTERACTION OF THE SEED TREATMENT WITH TRANSPLANT TREATMENT

	Auxin Used in Seed Treatment	Concen- tration of Auxin 1000 Ppm	Germination		Anthesis of First Blossom (Days after Planting)	Transplant Treatment				Total Yield (Pounds No. 1 Fruit)
			(Per Cent)	Coefficient of Velocity		Butyric		Naphthylacetic		
						Butyric	Naphthylacetic	Butyric	Naphthylacetic	
1	Naphthylacetic acid	1	80	7.09	21.8	23.7	70.6	28.0	119.1	43.7
2	Naphthylacetic acid	10	78	6.95	25.5	27.1	53.3	23.5	111.1	49.6
3	Naphthylacetic acid	100	74	6.74	31.7	28.3	34.3	26.6	88.3	40.1
4	Indolylbutyric acid	1	80	7.09	21.6	28.9	52.6	30.5	101.3	55.6
5	Indolylbutyric acid	10	74	7.02	24.3	25.1	50.2	40.6	75.0	69.6
6	Indolylbutyric acid	100	82	7.02	25.1	24.4	57.3	46.5	80.8	69.7
7	Phenylacetic acid	1	78	7.05	27.0	23.8	43.1	34.7	73.4	55.6
8	Phenylacetic acid	10	74	7.10	28.3	26.4	39.5	38.0	79.3	56.2
9	Phenylacetic acid	100	74	7.12	26.5	24.2	46.4	43.2	71.5	55.8
10	Indolylbutyric acid	1	74	7.05	26.1	24.9	44.3	43.5	71.2	57.3
11	Indolylbutyric acid	10	72	7.06	26.1	24.9	36.1	56.4	57.4	55.7
12	Indolylbutyric acid	100	56	7.07	26.8	27.4	36.9	29.6	56.9	44.7
Untreated check		0	52	7.07	29.6	33.1	26.1	26.4	58.7	53.1
Total			—	—	346.9	7.0	343.2	564.6	448.1	723.6
Significant Difference.			14.2	.068	4.7	26.6	17.7	39.0	28.1	26.1
			9.6	.046						



TABLE III—ANALYSIS OF VARIANCE OF DATA ON TIME OF BLOSSOMING, EARLY YIELD AND TOTAL YIELD OF TOMATO PLANTS THAT RECEIVED PHYTOHORMONE TREATMENTS

Source of Variance	Anthesis of First Blossom			Early Yield			Total Yield		
	D/F	Variance	"F"	D/F	Variance	"F"	D/F	Variance	"F"
Auxins in seed treatment . . .	3	3.78	.69	3	8.10	1.24	3	10.45	2.12
Concentrations of auxin in dust. . . . .	2	42.86	7.85**	2	8.91	1.37	2	24.77	5.02**
Transplant treatments. . . . .	1	21.60	3.95**	1	94.26	14.45**	1	219.51	44.52**
Within seed treatments. . . . .	9	6.10	1.12	5	659.02	101.23**	12	426.73	86.56**
Auxin X concentration. . . . .	6	123.00	21.00**	6	16.82	2.58**	6	8.35	1.69
Auxin X transplant treatment	3	26.14	4.79**	3	43.78	6.73**	3	103.49	20.99**
Concentration X transplant treatment. . . . .	2	5.40	.99	2	16.70	2.47	2	9.16	1.86
Transplant treatment X harvest date. . . . .	—	—	—	5	219.01	33.64**	12	10.99	2.23*
Auxin X concentration X transplant treatment	6	16.51	3.02**	6	31.91	4.90**	6	11.97	2.43*
Error (residual). . . . .	207	5.46	—	110	6.51	—	264	4.93	—
Total. . . . .	239	9.41	—	143	39.85	—	311	—	—

\*Exceeds value for 5 per cent point.

\*\*Exceeds value for 1 per cent point.

giving a highly significant "F" value. The average values given in Table IV for the three different concentrations indicate a tendency towards earliest flowering in the lowest concentration with flowering becoming later as the concentration increased. (c) The two transplant treatments significantly differed from each other in time of blooming (at odds of 20:1). The naphthylacetic solution transplant treatment gave slightly earlier flowering in general, than the indolylbutyric treatment. However, because of the small difference, it is of questionable significance. (d) The highly significant "F" value for the interaction; auxin in seed treatment x concentration of auxin, indicates that the different acids in the seed treatments were effective at different concentrations in causing early flowering. This can be seen in Table IV. Naphthylacetic acid was most effective when present in the dust in the low concentration (1,000 parts per million) and clearly caused later flowering as the concentration increased. Indolylbutyric caused earlier flowering in the medium and high concentrations, phenylacetic apparently appeared to slightly inhibit flower formation in the medium concentration while indolylacetic acid was most effective at the two lower concentrations. (e) The significant interaction of seed treatments x transplant treatments indicates that the effectiveness of the various seed dust treatments was dependent, in part, upon the transplant treatment, *i. e.* whether naphthylacetic acid or indolylbutyric acid was used. (f) There was no relationship between concentration of auxin in the seed treatment and the effectiveness of the transplant treatment or conversely between the effectiveness of any given concentration of auxin in the seed treatment and the subsequent transplant treatment. This is shown by the non-significant "F" value for the interaction of concentration x transplant treatment. (g) The effect of any one phytohormone upon the seeds was dependent upon the concentration of the auxin in the seed treatment and also upon the particular transplant treatment of the plants. It is apparent that the most effective combi-



nation for early flower production was the dust treatment of the seed with the low concentration (1,000 parts per million) of naphthylacetic acid and the subsequent use of indylbutyric acid (10 parts per million) solution in which to dip the roots as a transplant treatment. The use of naphthylacetic acid in the transplant treatment appears to have had an inhibiting effect upon flowering of those plants from seed which had been treated with naphthylacetic acid.

*Yield of Ripe Fruit:*—Since one of the important considerations of this study was the effect of the treatment upon the early production of fruit, the yield data are presented for two periods: (a) the first 24 days of the fruiting period and (b) the total yield for the season. Yield data are presented in Tables II and IV and shown graphically in Fig. 2. When comparisons are made at the 1 per cent and 5 per cent

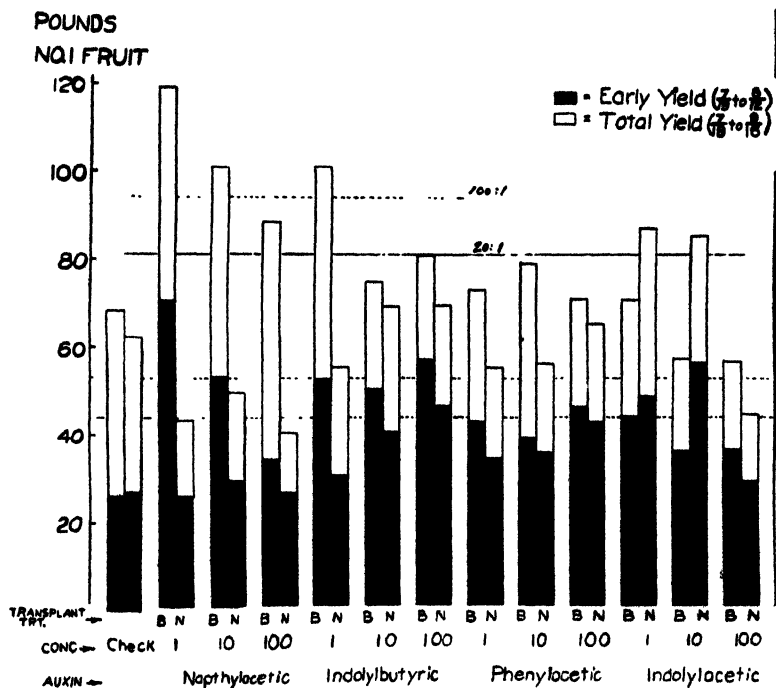


FIG. 2. Early and total yield of tomato plants as affected by various phytohormone treatments of the seeds and transplants. Horizontal lines across bars indicate significantly higher yields than checks at the 1 per cent and the 5 per cent levels.

levels of significance, the yield of plants in the various treatments for early and total production fall into the following groups:

1. Treatments outyielding check in EARLY production:

At 1 per cent level; indylbutyric transplant treatment 1, 2, 4, 6  
naphthylacetic transplant treatment 11

- At 5 per cent level ; indolylbutyric transplant treatment 1, 2, 4, 5, 6,  
9, 10  
naphthylacetic transplant treatment 6, 10, 11
2. Treatments outyielding check in total seasonal production :  
At 1 per cent level ; indolylbutyric transplant treatment 1, 2, 4  
naphthylacetic transplant treatment None  
At 5 per cent level ; indolylbutyric transplant treatment 1, 2, 3, 4, 6  
naphthylacetic transplant treatment 10, 11

It can readily be seen that there was a tendency for the plants given the indolylbutyric transplant treatment to produce a greater early yield and greater total yield than those given the naphthylacetic transplant treatment. Pertinent values obtained from analysis of variance of the yield data are presented in Table III.

The difference between any two of the phytohormone seed treatments in early yield of fruit was not as great as the difference necessary for significance even at the 5 per cent level (14.5 pounds). However, when their yields are compared with that of the check it is seen that each of the four auxins used in the seed treatment caused an increase in early yield over that of the check that was significant beyond the 1 per cent point. In the last column in Table IV comparison of the average total yields for the different auxin seed treatments shows that there is not a significant difference between any of them. Comparison with the yield of the check plants (from untreated seed) at the 1 per cent level of significance indicates that the plants from both the naphthylacetic treated seeds and those from the indolylbutyric seed treatment yielded a significantly greater poundage of No. 1 fruits for the entire season than did the plants from untreated seeds. At the 5 per cent level of significance all the phytohormone treatments of the seeds resulted in increased total fruit yield over that of the check.

The different concentrations of the auxins in the seed treatments caused a sufficiently great difference in total yield to produce a significant "F" value. In early yield, the difference between different concentrations was not significant. The average yields of the different concentrations do not differ from each other in early yield but in total yield the two lower concentrations outyielded the highest concentration at the 5 per cent level and the lower concentration still showed a significant difference at the 1 per cent level when compared to the yield of the highest concentration. This indicates that the effect of the lowest concentration was not influential upon the yield response of the plants until the latter part of the growing season.

The "F" value for "Transplant Treatments" exceeded the 1 per cent point both in the analysis of variance of early yield and of total yield. Reference to Table II shows that in both early and total yield, the plants in the indolylbutyric transplant treatment exceeded the yield of the plants in the naphthylacetic transplant treatment by a difference much greater than that required for significance at the 1 per cent level.

The effect of these treatments upon the plants is thought to have been principally upon the root system (2). This assumption then leads to the conclusion that those plants receiving the indolylbutyric acid

transplant treatment produced a larger and more branched root system than did those plants given the naphthylacetic acid transplant treatment. The difference in response is thought to be the result of too concentrated a solution of the latter to produce the same response as the same concentration of indolylbutyric acid. Probably a more dilute solution of naphthylacetic acid than that used in this experiment (10 parts per million) would be just as effective as the indolylbutyric appeared to be at this concentration.

Grace (2) has pointed out that the response of plants to phytohormone treatments varies with soil fertility.

The response obtained by use of the phytohormone treatments in this experiment is probably greater than would be obtained in a soil containing a greater quantity of organic matter and a higher level of fertility.

#### SUMMARY AND CONCLUSIONS

Treatment of tomato seeds with auxin-talc dust mixtures and the subsequent treatment of the plants with solutions of either indolylbutyric or naphthylacetic acid at the time of field transplanting showed that certain combinations and use of the proper concentration may result in: (a) marked acceleration of the time of anthesis of flowers; (b) production of a greater yield of fruit during the first month of the fruiting period; and (c) a greater total yield of marketable fruit for the entire season.

The effective concentration of naphthylacetic acid in the dust mixture for seed treatment appears to be considerably lower than that for any of the other acids used. Naphthylacetic acid in talc in concentrations of 10,000 parts per million and 100,000 parts per million caused marked inhibition in rate of seed germination and time of flowering of the plants in the field. Greatest acceleration in flowering and fruit production and the greatest total yield was caused by the treatment of 50 seeds with approximately 15 milligrams of a dust mixture consisting of 10 milligrams of naphthylacetic acid to 10 grams talc, followed by dipping the plant roots in an aqueous solution of indolylbutyric acid (10 parts per million) for about 2 seconds at the time of transplanting.

Naphthylacetic acid solution as a transplant treatment in the concentration of 10 parts per million appeared to be inhibitory to flowering and fruiting of the plants in the field in all instances except where indolylacetic acid was used in the dust mixture for treatment of the seeds.

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## Use of Nutrient Solutions and Hormones in the Water for Transplanting Tomatoes and their Effect on Earliness and Total Yields<sup>1</sup>

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**T**OMATO plants for commercial canneries in New York State are either local greenhouse and coldframe plants grown in rather crowded flats or southern field grown plants. In either case the plants are likely to be somewhat starved, or at least very low in minerals at the time they are transplanted to the field. It is a common practice of the growers to transplant the tomatoes with a transplanting machine which ejects from  $\frac{1}{2}$  to 1 pint of water around the roots as the plant is inserted in the soil. From 2 to 5 pounds of sulphate of ammonia or of nitrate of soda per 50 gallons of water is used commonly in the transplanting water.

Last year at Indianapolis, Baker (1) reported increased yields of tomatoes and earlier ripening where commercial phosphoric acid and also where mono-ammonium phosphate were used in the transplanting water. Grace (2) has reported tests of various hormones added to the soil and to nutrient solutions. He reported better results from very minute quantities of hormones and stated that with tomato seedlings increased growth was obtained with naphthylacetic acid at a rate corresponding to 200 milligrams per acre. Such small quantities would add only about one dollar per acre to production costs and therefore merited field tests to see if they would produce economical gains in yields.

Accordingly these treatments and several others devised by the author were compared in a field test with cannery tomatoes at the New York State Experiment Station, Geneva, in 1938. The plants were grown in accordance with the best commercial practices in growing plants for the cannery crop. Baerosa tomato seed was sown April 1st and the seedlings pricked off into composted soil in 16 x 22 inch flats setting 108 plants per flat. They were moderately hardened in coldframes and transplanted to the field on June 2nd. The field was a well drained Ontario loam soil which had been fertilized with a commercial brand of 4-16-4 fertilizer drilled broadcast at the rate of 800 pounds per acre 2 days before the tomatoes were transplanted to the field. The plants were spaced 3 feet apart in the rows and the rows 5 feet apart. One pint of water was poured in the hole as each plant was transplanted to the field. The experiment consisted of a comparison of 10 different treatments applied in this transplanting water. Each treatment included 21 plants per row replicated five times in randomized arrangement.

Table I shows yields of marketable tomatoes from each treatment calculated on an acre basis and arranged in the order of the early yields.

<sup>1</sup>Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 306.

The yield records are divided into three increments, namely, early yields, that is the crop harvested to August 30; mid-season yields, that is, the yields from August 31 to September 9; and late yields, that is, the crop harvested from September 10 until the last picking on September 26. The total yields are also given and with each yield increment is also given its difference (gain or loss) as compared with the check treatment (water only). By dividing the yield records into these three groups the effect of each treatment on earliness of maturity as well as on total yields is well illustrated. For example, the first four treatments listed in Table I show significant gains over the check treatment in early and mid-season yields though in the last pickings the check treatment yielded more but not enough to equal the total yields of the preceding treatments.

TABLE I—EFFECT OF NUTRIENTS AND HORMONES IN TRANSPLANTING WATER FOR TOMATOES (1938)

No.	Nutrients per 50 Gallons Water 1 Pint per Plant	To August 30		August 31 to September 9		September 10 to September 26		Total Yields	
		Tons per Acre	Gain or Loss	Tons per Acre	Gain or Loss	Tons per Acre	Gain or Loss	Tons per Acre	Gain or Loss
1.	20 ounces Ammo Phos A +10 ounces nitrate of potash . . . . .	2.76	1.44	3.32	1.35	2.17	-.94	8.25	1.85
2.	20 ounces Ammo Phos A +10 ounces KNO <sub>3</sub> + 1 ounce borax +4 ounces MnSO <sub>4</sub> +4 ounces MgSO <sub>4</sub> . . . . .	2.63	1.31	3.07	1.10	2.24	-.87	7.94	1.54
3.	20 ounces Ammo Phos A +10 ounces KNO <sub>3</sub> +50 milligrams Naphthylacetic Acid . . . . .	2.45	1.13	3.29	1.32	2.37	-.74	8.11	1.71
4.	10 ounces Ammo Phos A +10 ounces calnitro +10 ounces KNO <sub>3</sub> . . . . .	1.81	.49	2.71	.74	2.76	-.35	7.28	.88
5.	500 cubic centimeters ortho phosphoric acid +10 ounces KNO <sub>3</sub> . . . . .	1.60	.28	2.66	.69	2.54	-.57	6.80	.40
6.	2 pounds sulphate of ammonia . . . . .	1.46	.14	2.38	.41	3.37	.26	7.21	.81
7.	500 cubic centimeters ortho phosphoric acid . . . . .	1.37	.05	2.20	.23	2.94	-.17	6.51	.11
8.	Water only (check) . . . . .	1.32	—	1.97	—	3.11	—	6.40	—
9.	50 milligrams naphthylacetic acid . . . . .	1.08	-.24	2.20	.23	3.15	.04	6.43	.03
10.	250 milligrams indolylbutyric acid . . . . .	1.01	-.31	1.90	-.07	3.54	.43	6.45	.05
	Difference required for significance . . . . .	—	.48	—	—	—	—	—	1.02

Table I shows that treatments no. 1, 2 and 3, each of which contained 20 ounces of Ammo Phos A (11 per cent N, 48 per cent P<sub>2</sub>O<sub>5</sub>) and 10 ounces of nitrate of potash (13 per cent N, 44 per cent K<sub>2</sub>O fertilizer grade) per 50 gallons of water produced significantly higher early yields of tomatoes than any of the other treatments and that this increased early crop resulted in the largest total yields. The differences in yield between treatments 1, 2 and 3 were not significant. Hence it is clearly evident that the 20 ounces of Amino Phos A plus 10 ounces of nitrate of potash which was common to these three treatments was the important factor in increasing the yields of tomatoes.

The largest early yield and also the largest total yield were obtained from treatment no. 1 which consisted only of 20 ounces of Ammo Phos A and 10 ounces of nitrate of potash per 50 gallons of water. With plants spaced 3 feet x 5 feet and 1 pint of solution per plant, 363 gallons would be used per acre. This would require 9 pounds of Ammo

Phos A and  $4\frac{1}{2}$  pounds of nitrate of potash, and would cost only 48 cents for these materials per acre. This small amount of chemicals increased the early yield by 1.44 tons and the total yield by 1.85 tons per acre. Such a large gain at small cost shows the practical value of the treatment.

It seems surprising that such small quantities of nutrient material used in a well-fertilized field would make such a striking difference in the yields of tomatoes. The most probable explanation is that this nutrient solution was applied in a particularly available form just at a critical time in the growth of the plants when they were low in minerals, and enabled those plants to withstand better the shock of transplanting and to become established quickly and grow vigorously from the time they were transplanted. Within 2 weeks after transplanting the five replications of this treatment and the five replications each of treatments no. 2 and no. 3 (both of which also contained 20 ounces of Ammo Phos A and 10 ounces of nitrate of potash) showed a very outstanding increase in size and vigor of plants. No doubt the marked increase in early and total yields (Table I) resulted from this early stimulation of the plants.

Treatment no. 2 contained the same amount of Ammo Phos A and nitrate of potash as treatment no. 1, but no. 2 also contained small amounts of the minor elements, namely, 1 ounce of borax, 4 ounces manganese sulphate and 4 ounces magnesium sulphate per 50 gallons of water. Possibly this resulted in a toxic concentration of one of these salts and apparently their absence was not limiting to plant growth, for the early and total yields were greater in treatment no. 1, which did not contain these additional chemicals.

#### HORMONES DELAYED MATURITY

Treatment no. 3 contained 50 milligrams naphthylacetic acid per 50 gallons of water in addition to the same amount of Ammo Phos A and nitrate of potash contained in treatment no. 1. This small amount of hormone approximates the total amount recommended by Grace (2). He made periodic applications of this hormone at lower concentrations and to younger plants, but his total dosage approximated the amount used in the single application in treatment no. 3. In the experiment herein reported the hormone had a depressing effect on yields, particularly the early yields, and better results were obtained without the hormone.

The delaying effect of this hormone on maturity is again evident in the yields from the no. 9 treatment (50 milligrams naphthylacetic acid in 50 gallons of water). The early yield from this treatment was not as great as where water only (no. 8) was used.

Treatment no. 10 (250 milligrams indolybutyric acid) containing five times as much hormone had a still greater delaying effect on maturity as shown in Table I. The lowest early yields were obtained from this treatment. The poorer results from the greater amount of hormone is in agreement with the statement by Grace (2) that the hormones are more effective in very dilute concentrations.



## AMMO PHOS "A" MOST EFFECTIVE

Treatment no. 4 contained only half as much Ammo Phos A (10 ounces) as no. 1, but contained 10 ounces of calnitro to give the equivalent amount of nitrogen as in no. 1, and also contained the same amount of nitrate of potash (10 ounces). The large reduction (1 ton per acre) in early yields and total yields of no. 4 as compared with no. 1 is statistically significant and shows the marked effectiveness of the phosphorus in Ammo Phos A (no. 1 had twice as much) in increasing early and total yields.

The poorer results obtained in treatment no. 5 (500 cubic centimeters ortho phosphoric acid and 10 ounces nitrate of potash) and the still poorer results from treatment no. 7 (500 cubic centimeters ortho phosphoric acid) as compared with treatment no. 1 show that the mono-ammonium phosphate was a significantly more effective form of phosphorus than the ortho phosphoric acid in stimulating plant growth.

Sulphate of ammonia in the transplanting water (treatment no. 6) had little effect on the early growth or early yields of the plants, but it is interesting to note that the largest late yield was obtained from this treatment.

A statistical analysis of the early yields according to the methods described by Love (3) shows that treatments nos. 5, 6, 7, 9, and 10 produced no significant differences as compared with the check treatment (no. 8). However, treatment no. 5 was significantly better than treatments nos. 9 and 10. Treatments nos. 1, 2, 3, and 4 all produced significantly better early yields than the check treatment and better than treatments nos. 9 and 10. Treatments nos. 1, 2 and 3 produced significantly better early yields than any of the other treatments, but the differences between these three were not significant.

In total yields, treatments nos. 1, 2 and 3 were again significantly better than any of the others and the differences between these three treatments were not significant. There were no significant differences between the total yields of any of the remaining seven treatments. Consequently, with the exception of treatment no. 4, the same conclusions would be drawn from the early crop as from the total yields. Treatment no. 4 showed a slightly significant gain in early yield, but the gain was not of statistical significance in the total yields. Evidently there was not sufficient phosphorus in this treatment to effect an important gain in yield.

Summarizing the results briefly, it should be noted that in the quantities and methods used in this experiment the hormones were not effective in increasing yields of tomatoes and tended to delay maturity. Also, the use of small amounts of borax, manganese sulphate, and magnesium sulphate in the transplanting water did not increase the yields. The use of ortho phosphoric acid, and also of sulphate of ammonia in the transplanting water gave small but insignificant gains in yields of tomatoes. But 31 cents worth of Ammo Phos A, plus 17 cents worth of nitrate of potash per acre used in the transplanting water produced significant gains and increased the yield of early tomatoes by 1.44 tons and the total yield by 1.85 tons.

It should be noted that this is only one year's results. However, the outstanding superiority of all replicates that received the Ammo Phos A (11 per cent N, 48 per cent  $P_2O_5$ ) plus nitrate of potash (13 per cent N, 44 per cent  $K_2O$ ) in the transplanting water made this particularly noteworthy as a promising treatment that merits further trial under various conditions. It is not likely to be as effective with plants, as commonly grown by market gardeners, which are liberally fertilized and more widely spaced up to the time they are transplanted to the field. It seems reasonable to expect that this treatment would be particularly effective with cannery tomatoes, because either southern grown plants or local greenhouse and coldframe grown plants are likely to be partially starved and quite low in minerals at transplanting time. Consequently, a most advantageously placed supply of readily available nutrients just at this critical period as they are transplanted is most likely to be effective in earlier stimulation of the plants and to result in increased early and total yields.

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# Classification of Tomato Varieties According to Physiological Response

By V. A. TIEDJENS and L. G. SCHERMERHORN, *New Jersey  
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**A** COMPARISON of the numerous varieties of tomatoes being grown in the coastal plain states suggests the possibility of an arbitrary classification based on plant characters and responses that may be helpful in judging the adaptability of varieties for local conditions.

In any large collection of varieties and seedlings we may expect a wide variation in types of fruit and plant characters. In selecting desirable varieties we eliminate the extreme types which are undesirable for economic purposes. The others are potential varieties. Whether they are sufficiently worthy to become popular commercial varieties actually depends upon their ability to produce large yields of fruits of acceptable quality under a rather wide range of environment. Even though a variety may inherit desirable fruit characters, good crops of desirable fruit do not result unless associated with the functioning of an adequate plant. Favorable growth and successful fruiting of a tomato plant is determined by a number of environmental factors including light, moisture, temperature and nutrition. Since under field conditions these factors vary considerably, a satisfactory variety of tomato must be somewhat adaptable to environment. Furthermore, its own varietal response to the various factors of environment should be known in order to provide efficient culture.

## VARIATIONS IN VARIETAL FRUITFULNESS

Varieties of tomatoes vary greatly in their inherited degree of fruitfulness and vigor. The two extremes may be described somewhat as follows: (a) varieties which are highly floriferous and fruitful with a relative small amount of foliage and which require a high level of fertility and a favorable environment; and (b) varieties which are highly vegetative, distinctly less floriferous and fruitful and which are easily induced to become unfruitful with optimum conditions for growth. The greater number of commercial varieties are intermediate types between these two extremes and a somewhat more detailed classification is needed.

## CLASSIFICATION

The following classification has been arranged for the purpose of grouping varieties according to their capacity for fruitfulness and growth: 1, highly fruitful, but weakly vegetative; 2, fruitful, but fairly vegetative; 3, fruitful, but medium vegetative; 4, fruitful, but strongly vegetative; and 5, fruitful, but very strongly vegetative.

Most of our present varieties would fit into these groups with some slight variations. These genetic differences are reflected in their meta-

bolic or respirational rate which increases with temperature. The highly vegetative types have a high metabolic rate while the highly fruitful types have a relatively lower rate.

Nightingale (1) in studying the relation of temperature to metabolism in the tomato found that carbohydrates were very high at 55 degrees F, while only moderately high at 70 degrees F where they made a firm, but rapid growth, whereas at 95 degrees F the plants could not manufacture carbohydrates rapidly enough to balance the rapid breakdown due to respiration and the plants died. It was further shown that nitrate absorption tended to hasten respiration. From these results we may assume that the capacity of the plant to retain its carbohydrates determines its adaptability to nutritional levels as well as climatic factors.

Nightingale and Blake (2) have shown that temperature plays an important role in the metabolism of apple and peach varieties and that the rapidly growing varieties have a higher respirational rate, that is, they burn up carbohydrates more rapidly at higher temperatures.

Assuming that tomatoes would respond in a similar manner five different varieties were selected which were representative of three of the classes previously described: Class 3, Pritchard and Bonny Best; Class 4, Globe and Marglobe; Class 5, Rutgers.

These were grown at six different root temperatures of 55, 60, 65, 70, 80, and 90 degrees F. The air temperature was approximately 58 degrees F at night and approximately 20 degrees F higher during the day time.

#### RESULTS OF TEMPERATURE STUDIES

Considering all varieties the best growth and fruitfulness were obtained when the root temperatures ranged at or between 65 and 80 degrees F. There were, however, marked differences in response shown by the different varieties. The varieties that possessed the highest rate of metabolism (Class 5) made greatest response to low temperatures and were most adversely affected by the high temperatures. In contrast, the varieties that possessed the lowest rate of metabolism (Class 3) made growth at the low temperatures and were least affected by the high temperatures.

The results obtained in the root temperature studies in tomatoes agree with those obtained by Nightingale (1) on tomatoes and by Nightingale and Blake on apples and peaches (2).

When the root temperatures were raised high enough to inhibit fruit set in Rutgers (Class 5) the starch content present in the late afternoon completely disappeared during the night. A negative test for starch was obtained in the pollen grains. In contrast the pollen from plants which set fruit freely always gave a positive test for starch. It would seem from these observations that root temperatures regulate the rate of nitrate or ammonium assimilation in the roots and respiration of carbohydrates in the roots and tops more or less independent of air temperatures. Furthermore, varieties have a definite temperature requirement which affects their nitrogen needs. For field crops this information has practical value in that we can select our soils, supply nitrogen more

judiciously and make the proper use of mulching material.

We can pick the fields and areas where varieties are best suited and prescribe the conditions under which they should be grown. We certainly should not expect a good crop of Rutgers and Pritchard in the same field with the same fertility treatment. Pritchard (Class 3) is a firm foliage type of plant that requires a high level of fertility, particularly nitrogen, to produce a big yield and does not respond readily to side dressings late in the season. It is our experience from field plots that anything short of this means poor yields. Rutgers (Class 5), on the other hand, is a free growing type that can use nitrogen freely at lower temperatures and makes a rapid response to side dressings of fertilizer. Conditions suitable for Pritchard tend to promote soft, succulent foliage and sterility in Rutgers.

In any study of the comparative value of a new variety of tomato it is of great importance to classify the plant on the basis of its vegetation response.

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# The Importance of Potassium in the Growth of Vegetable Plants

By V. A. TIEDJENS and M. E. WALL, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

**A**LTHOUGH the effect of potassium on plant metabolism has been studied by numerous investigators (1, 4, 5, 6), there still remain many unsolved problems relating to the function and effects of potassium on plant processes. The purpose of this paper is to present a summary of the results of experiments conducted from 1936 to 1938 in the Department of Vegetable Gardening at the New Jersey Agricultural Experiment Station on the effects of potassium on the Rutgers tomato plant. In all of the experiments conducted the plants were grown in sand culture, and the nutrients were supplied by means of a constant drip (8).

## POTASSIUM DEFICIENCY SYMPTOMS

In all the experiments conducted, the Rutgers tomato plant, grown with a minus potassium nutrient, exhibited characteristic potassium deficiency symptoms. The presence of sodium in the nutrient solution replacing potassium (8) in no way prevented the onset of deficiency symptoms.

There were two characteristically different stages of potassium deficiency in the Rutgers tomato when nitrate was the source of nitrogen. The first stage, which may be absent under some conditions, appeared 2 to 4 weeks after the plants were fed on a minus potassium nutrient solution. The plants became very hard and chlorotic (8), very often accompanied by an intense anthocyanin pigmentation of the upper portion of the stem and petioles. There is a marked retardation of growth, elongation of the stem practically ceases, and the stem is comparatively small in diameter. Fruit usually sets earlier in the deficient plants, but the ovary may drop off due to the formation of an abscission layer in the pedicel. Microchemically, these plants showed a very high starch concentration. Macrochemical analysis verified this and also revealed a high total sugar concentration. These concentrations were much higher than those of plants grown on a plus potassium nutrient.

This first stage of potassium deficiency was quite transitory, lasting from 1 to 2 weeks. Then the stem began to elongate and the color of the upper leaves became much greener and the plants became very succulent. This was soon followed by brown, peppery spots on the lower leaves, while the edges of these leaves curled upward due to uneven growth. The injury became progressively more severe, and the lower leaves finally died. Eventually all the leaves except those near the tip were affected. Comparatively few fruits reached maturity. Those that did develop were small and several developed blossom-end rot. Microchemical and macrochemical analyses revealed very low

starch and total sugar content in contrast to normal plants and those showing early potassium deficiency symptoms.

Environmental conditions determined whether the first stage of potassium deficiency previously noted appeared. Plants grown in spring and summer with an abundance of light showed the initial hard stage of potassium deficiency. Plants grown at low temperatures in any season gave the same result. Plants grown in winter, in a shaded greenhouse in summer, or when grown at high temperatures, showed only the later symptoms of potassium deficiency. Tomato plants grown with ammonia as the source of nitrogen maintained at a suitable pH (7) also failed to go through the first stage of potassium deficiency. Instead the plants rapidly became very soft and practically all the leaves began to die within 1 to 2 weeks after they were given the nutrient solution. The foliage before dying became very dark green, much more so than where nitrate was the source of nitrogen. This was very similar to that observed in the field.

Micro analyses have always shown an accumulation of carbohydrates during the early "hard" stage of potassium deficiency. An abundance of light during the first few weeks that the plants were grown on a potassium deficiency solution was responsible for the production of sufficient carbohydrate to accumulate when the nitrogen metabolism of these plants was disorganized as a result of a deficiency of potassium. It seems that some stage of the nitrogen metabolism may be checked by the absence of potassium, and utilization of carbohydrates stops. This accumulation was of short duration, however, because carbon dioxide assimilation was likewise checked as a result of potassium deficiency. Plants grown in winter did not form sufficient carbohydrates to accumulate due to the low intensity of sunlight under the conditions prevailing when this experiment was conducted. This explanation accounts very satisfactorily for the accumulation of carbohydrates, and the accompanying external symptoms. What phase of the nitrogen metabolism is involved and whether it is direct is very difficult to determine (5, 6, 8).

During the later stage of potassium deficiency, carbohydrates materially decreased. This was confirmed by several experiments. These results are in harmony with other investigators who have found that carbon dioxide assimilation decreases and respiration increases progressively as potassium deficiency becomes more severe (3). The final stages of potassium deficiency in the tomato plant are associated with carbohydrate starvation and since the lower leaves had the lowest potassium content, the carbohydrates also were lowest in these leaves. Therefore, the lower leaves always died first.

Low temperature checked respiration and nitrogen assimilation and since potassium deficiency also checks nitrogen assimilation the initial high carbohydrate stage will be exhibited. High temperatures apparently increased nitrogen assimilation and respiration, and carbohydrates did not accumulate to any great extent in the potassium deficient plants as it did at lower temperatures.

Supplying plants with ammonium nitrogen tends to decrease greatly the carbohydrate concentration (7). Potassium deficiency, accentuates

this reduction of carbohydrates. Hence, the rapid onset of the second type of potassium deficiency symptoms in plants grown with ammonium nitrogen is to be expected.

#### MINIMUM LEVEL OF POTASSIUM IN SAND CULTURE

In an experiment in which varying amounts of potassium were supplied to tomato plants, those receiving 40 parts per million produced the most dry matter and fruit. Plants grown on 20 parts per million did not show severe leaf breakdown, but were somewhat stunted and did not set fruit well. All plants grown on concentrations of potassium between 0 and 20 parts per million showed severe leaf breakdown, characteristic of potassium deficiency.

Carbohydrate analyses of the leaves showed that the plants grown on 40 parts per million of potassium had the highest carbohydrate content of any of the plants grown. Since a fairly high carbon-nitrogen ratio favors a good set of fruit, the high carbohydrate content of the 40 parts per million plants was undoubtedly responsible for their higher yield of fruit. Materially increasing the potassium tended to reduce carbohydrates.

Gassner and Goeze (2) report a "low but optimum concentration of potassium" for barley. This would seem to correspond to tomato plants grown with 40 parts per million of potassium. Recent evidence from experiments under way in the vegetable greenhouses at New Brunswick seems to indicate that the calcium to potassium ratio may be responsible for the greater dry matter in tomato receiving 40 parts per million of potassium. A calcium to potassium ratio of 5 to 10 parts of calcium to 1 of potassium has given the most dry matter in onion bulbs and greatest fruit set in tomato in these experiments. However, the potassium concentration must be at least 40 parts per million. Calcium to potassium ratios of 40:8 or 40:4 resulted in potassium deficiency because too little potassium was present.

#### EFFECT OF POTASSIUM ON CALCIUM ABSORPTION

Investigations on the effect of potassium on calcium absorption gave striking results. Tomato plants were grown with 20 parts per million of calcium, but varying amounts of potassium, (4, 8, 20, 40, 80, 160, and 320 parts per million). Those plants receiving 4, 8, and 20 parts per million of potassium showed potassium deficiency, but little or no calcium deficiency. The remaining series showed no potassium deficiency, but progressively severe calcium deficiency symptoms. Plants receiving 160 and 320 parts per million of potassium showed extremely severe injury due to calcium deficiency. The stem tips and upper leaves on these plants died off completely. It is interesting to note in conjunction with these results, that plants grown on 40 parts per million of calcium showed no symptoms of calcium deficiency when even 320 parts per million of potassium were used.

From the above observations it would seem that calcium and potassium antagonize each other and that the decrease in carbohydrate



formation in cases of potassium deficiency may be due to injury of protoplasm, because ion balance is lacking, rather than to any specific catalytic action of potassium.

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# A Trace Element Deficiency on the Tomato

By JACKSON B. HESTER, *Riverton, N. J.*

**I**N nutritional investigations with the tomato during the winter months of last year a malnutrition developed in a number of plants in pots that was not corrected by nitrogen, phosphorus, potash, calcium or magnesium applications. There were located in the greenhouse 110 3-gallon glazed pots involving studies of various kinds on three different virgin soil types, the Sassafras sandy loam, Elkton sandy loam and Portsmouth loamy fine sand. The symptoms started first in plants in the Sassafras sandy loam on the moderately high limed soil but finally developed in practically all of the pots. Since the symptoms were common to all treatments and have not been described, to the knowledge of the author, a description is being given.

## DESCRIPTION OF THE MALNUTRITION

The malnutrition started first on plants which had made the most growth; that is, on the moderately high limed soils, but with the second crop upon these same soils it developed on the young plants. It started in the tips of the terminal leaflet involving first only a tiny portion, but later involving greater portions of the leaflet and other leaflets on the leaf. The symptoms, however, always showed on the bottom or oldest leaves of the plant first. The first appearance was a yellowing of the tip portion with prominent pink veins in the area affected. Under some conditions the first yellowing of the leaf was followed by purplish areas on the under surface of the leaf. From the yellow portion rather large orange spots occurred which rather rapidly turned brown and decayed. At about this stage of development the symptoms spread up the plant rather rapidly with larger portions of the plant becoming yellow. The plant gave the appearance of having matured before time.

Suspecting a trace element deficiency all of the even pots were treated with the following amounts of certain elements: copper, 0.025 grams; manganese, 0.04; zinc, 0.02; boron, 0.015 and cobalt, 0.024. The malnutrition was immediately stopped and two subsequent crops showed no signs of the deficiency on these pots. It was observed in this study that this quantity of the trace elements decreased the yield of vegetation on soils below pH 6.1 but increased it between pH 6.1 and 7.0. An analysis of the vegetation showed that the manganese content of the plant had been greatly increased amounting to ten times the percentage at the higher pH values. Since there was considerable water-soluble manganese at pH values below pH 5.6 in the soil, it was assumed that the manganese had decreased the yield by having actually become toxic to the plants.

A further observation was made about the fruit from the plants receiving the trace elements. In every case analyzed the juice had a pH value of approximately 0.2 of a unit higher than the fruit from plants receiving no trace elements.

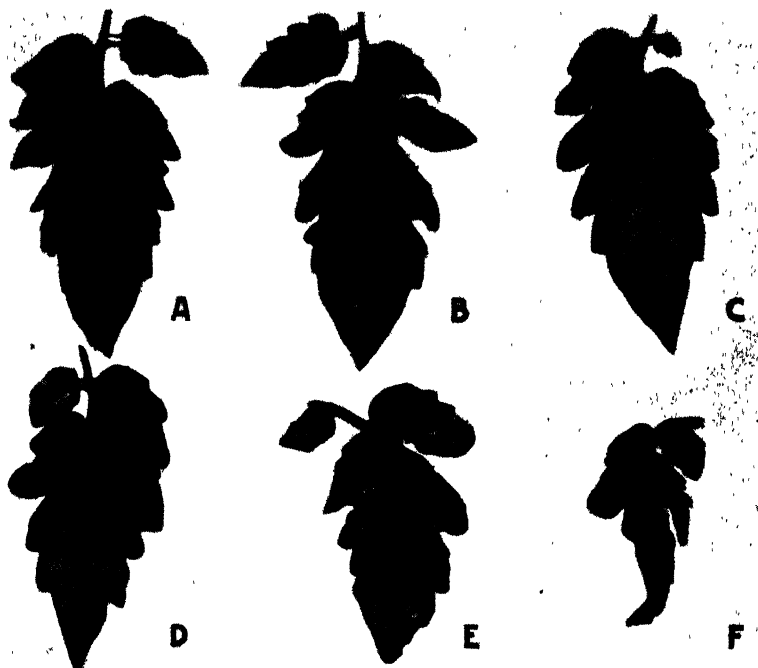


FIG. 1. A type of breakdown in the tomato leaf associated with boron deficiency. A, normal leaflet; B, first signs of deficiency-yellowing with pink veins; C, later development, orange spots; D, browning of orange spots; E, breakdown of leaflet; and F, breakdown of the entire leaflet.

In order to ascertain which element was correcting the deficiency a series of pots was set up using each element separately and in combination. One tenth of a gram of the element was used in each case. Boron or boron combined with the other elements seemed to be the only one to correct the condition. However, 0.1 gram of boron was sufficient to burn the tips of the plant. This burning followed on other crops even after severe leaching of the soil.

#### CONCLUSION

Boron deficiency symptoms have been reported on the tomato before (1, 2, 3) but the symptoms were apparently entirely different. For the most part these symptoms have been made in water or sand culture. It is entirely possible that only a partial deficiency exists which may be associated with other elements absorbed by the plant from the soil that was not present in the former studies. While only one or two cases were noted in the field this past season it may be more common than is expected. From the above study the conclusion was drawn that extreme care must be exercised in applying trace elements to tomatoes.

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## Varietal, Climatic and Age Influences on Daily Cracking Indices of Tomato Fruits

By W. A. FRAZIER,<sup>1</sup> *University of Arizona, Tucson, Ariz.*, and  
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## ABSTRACT

This material will be published in full in a Maryland Agricultural Experiment Station Bulletin.

FOR two field-grown crops, high susceptibility of Earliana and Grothens Red Globe varieties to concentric cracking was shown. High susceptibility of Marglobe and Dwarf Champion to radial cracking was found. Browns Special was comparatively resistant to both types of cracking.

Studies in 1937 showed that cracking was initiated approximately 10 days previous to the pink stage of maturity. Daily cracking indices increased up to the pink stage and were high for a few days thereafter. Cracking progressed daily, even when atmometric readings indicated continued evaporation. Night evaporation was either slow, or nil, however.

Daily increments in fruit size, as measured by circumference values, had begun to decrease when cracking began. No consistent relation was found between daily growth increments, as measured, and cracking indices under these conditions.

<sup>1</sup>A report of experimental work done while the senior author was a member of the staff of the Maryland Agricultural Experiment station.

# The Influence of Bordeaux Spray on the Growth and Yield of Tomato Plants<sup>1</sup>

By VLADIMIR G. SHUTAK and E. P. CHRISTOPHER, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

THE tomato plant is attacked by a number of leaf diseases for which the recommended control has been Bordeaux mixture. While giving reasonable control of disease, Bordeaux has been said to retard ripening, reduce yield, and increase blossom end rot (1, 4).

The response of tomato plants to Bordeaux mixture may vary greatly with humidity, soil moisture, temperature and other factors (3). It has been shown that the carbon dioxide assimilation of plants growing under favorable conditions is not markedly influenced by Bordeaux 4-4-50 (2). Therefore, it was thought desirable to conduct an experiment to determine to what extent the above mentioned injurious effects of Bordeaux might be found under southern New England conditions.

Four hundred Marglobe tomato plants were set in the field (May 27, 1937) 2 feet apart in 4-foot rows. All plants were trained to a single stem and tied to stakes. Replicated plats of 10 plants each were sprayed with various Bordeaux sprays, using a Myers' knapsack sprayer. The spray was applied between 9:00 and 10:00 A.M. standard time, at 2-week intervals, starting June 22. Approximately 1 liter of spray was used per plant. Bordeaux was prepared from high calcium lime and commercial copper sulphate snow. The diluted lime solution was added to the diluted copper sulphate solution. The standard Bordeaux formula 4-4-50 was taken to mean 4 pounds of copper sulphate, 4 pounds of stone lime and 50 gallons of water. Dragon Mainrok Lime sold as hydrated lime was used at the rate of 1.32 parts of the hydrate for each part of stone lime called for in the formula.

Three Bordeaux formulas were used: 4-4-50, 4-12-50, and 12-4-50. A 12-4-50 Bordeaux gave a definite test for copper with potassium ferrocyanide. The high lime Bordeaux gave a very pronounced residue.

Growth measurements, notes on leaf condition, and yield records were taken at regular intervals. Marked differences in leaf condition were noted very early in the experiment.

Table I gives data on the growth of the plants during the season. In spite of the fact that the 12-4-50 Bordeaux mixture gave a positive test for copper with potassium ferrocyanide, it did not produce noticeable burning or stunting of the plants. This is quite contrary to the common belief that a Bordeaux mixture giving a positive test for copper is injurious to plants and should not be used for spraying. This formula proved to be better than any other formula tried. The residue on the plants and fruits was a little lighter than that on the plants treated with other Bordeaux mixtures.

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Excessive lime (4-12-50 Bordeaux mixture) was extremely injurious, causing a severe desiccation of young leaves and terminals. Plants sprayed with this formula made considerably less growth than those which were unsprayed. Both of the other formulas resulted in more growth than was secured from the check plants.

Another measure of the effectiveness of the sprays was the percentage of dead leaves on the plants. Death of leaves on the plant may be caused by disease, spray injury, or nutritional deficiencies. Since all plants received complete fertilizers, the injuries were probably due entirely to disease or spray. The record of dead leaves was not separated as to the cause because of the extreme difficulty of doing so

TABLE I—GROWTH IN HEIGHT OF BORDEAUX SPRAYED TOMATO PLANTS.

Treatment	June 23 to July 8 (Inches)	July 9 to July 17 (Inches)	July 18 to July 30 (Inches)	July 31 to September 30 (Inches)	Total for the Season (Inches)
Bordeaux 12-4-50	11.5	7.5	8.8	25.9	53.7
Bordeaux 4-4-50	11.8	6.4	8.6	26.1	52.2
Bordeaux 4-12-50	11.1	5.9	7.5	19.6	44.1
Unsprayed	11.8	6.9	8.7	22.7	50.1

accurately. The grower is primarily interested in the decrease in the number of functioning leaves from whatever cause. Sprayed plants in every case had a lower percentage of dead leaves than did unsprayed plants.

TABLE II—PERCENTAGE OF DEAD LEAVES ON BORDEAUX SPRAYED TOMATO PLANTS

Treatment	Record Taken				
	August 11 (Per Cent)	August 24 (Per Cent)	September 8 (Per Cent)	September 23 (Per Cent)	September 30 (Per Cent)
Bordeaux 12-4-50	13	25	41	50	53
Bordeaux 4-4-50	21	42	49	58	63
Bordeaux 4-12-50	55	52	66	70	78
Unsprayed	66	66	77	76	82

A 12-4-50 Bordeaux mixture (see Table II) controlled diseases very effectively without producing any visible injury in spite of the "free copper" present in the spray. A standard 4-4-50 Bordeaux mixture was also effective in keeping down the number of dead leaves. The high-lime spray was decidedly inferior. The ability of this spray to control disease could not be judged from these data because many of the leaves were injured and subsequently killed by the spray. It is certain that as far as maintaining a healthy foliage is concerned this spray is very unsatisfactory.

It is claimed that one of the main disadvantages of spraying tomato plants is less early fruit. The time of harvest was divided into three periods, early season from July 30 to August 16, mid-season from August 17 to September 5, and late season from September 6 to September 30. There were three pickings in each period and the fruits which were still green at the last picking were recorded separately.

TABLE III—THE RATE OF RIPENING AND TOTAL YIELD OF BORDEAUX SPRAYED TOMATO PLANTS

Treatment	Total Yield (Tons Per Acre)	Early Season (Per Cent)	Mid-Season (Per Cent)	Late Season (Per Cent)	Green at Last Picking (Per Cent)
Bordeaux 12-4-50.....	17.70	20.48	49.02	23.73	6.79
Bordeaux 4-4-50.....	16.92	28.20	37.67	24.97	9.17
Bordeaux 4-12-50.....	12.51	34.24	39.12	19.96	6.67
Unsprayed.....	15.51	32.51	52.30	13.72	1.48

Table III presents data which show a marked difference in yield under the various treatments. A higher yield was secured from both the Bordeaux 12-4-50 and 4-4-50 plats than from the unsprayed ones. High lime, 4-12-50, caused a marked reduction in yield but a larger percentage of the fruits ripened early. Since the unsprayed plants yielded more heavily throughout the season, the actual weight of fruit harvested during the early period was definitely in favor of no spray, followed in order by Bordeaux 4-4-50, 4-12-50, and 12-4-50. In the case of the Bordeaux 12-4-50, there was a marked increase in yield during the mid-season picking periods.

These data seem to support the claim that Bordeaux retards ripening to some extent but may control disease sufficiently well to increase the total yield during some seasons. It is also definitely indicated that high-lime Bordeaux should be avoided and that high-copper Bordeaux may be safely and satisfactorily used. Our observations indicate that the injury from lime must be considered along with possible copper injury.

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# The Preservation of Fresh Vegetables by Means of Wax Emulsions

By HANS PLATENIUS and L. L. MORRIS, *Cornell University, Ithaca, N. Y.*

## ABSTRACT

This material will be published as a bulletin of the New York (Cornell) Agricultural Experiment Station.

**T**HE rate of transpiration of vegetables after harvest can be reduced effectively by dipping them into a cold wax emulsion which deposits a thin film, only a few microns thick, on the surface of the vegetable. In many cases such films were found to reduce the rate of transpiration 30 to 50 per cent. While some relationship exists between the amount of paraffin present in the film and its water retaining properties the thickness of the film is not proportional to the degree to which transpiration is reduced. Preliminary experiments indicate that the wax film does not interfere seriously with the normal gas exchange through the epidermis. Nearly all the root crops, with the exception of parsnips, responded favorably to the treatment with wax emulsions containing a high percentage of paraffin. Cucumbers, tomatoes, eggplants, and peppers gave the best results when dipped into emulsions with a high content of carnauba wax. This type of wax gives the emulsion the required wetting properties and also leaves an attractive gloss on the surface of the waxed vegetables. The degree to which vegetables benefit from waxing depends not only on the kind of vegetable but also on the conditions under which they were grown, the method of applying the wax, the type of emulsion and its concentration used, and the rate at which the vegetables are dried after waxing. The waxing process was found to be unsuited for leafy vegetables and bunched root crops.



## The Use of Wax Emulsions in Reducing Desiccation Of Transplanted Tomato Plants and Apples in Storage

By S. E. JONES and H. W. RICHEY, *Iowa State College,  
Ames, Ia.*

**W**AX emulsions have been found to be very promising as an aid in transplanting of trees and shrubs in Ohio by Chadwick (1) and in Michigan by Miller, Neilson and Bandemer (2). This practice was readily adopted by growers and in 1932 more than 6,000,000 nursery plants were waxed. The workers in both Michigan and Ohio have stated that treating plants with wax emulsions is of greatest benefit when transplanting is done under trying conditions and that this practice will not overcome poor methods of growing and handling of nursery plants.

The successful use of wax emulsions on trees and shrubs led the writers to consider the possibility of treating vegetable plants, particularly in southern Texas where transplanting is done during the hot and dry summer months. Under these conditions it is frequently difficult to get a stand. The plants are set in dry ground and irrigated, but the shock of transplanting may kill them before a good root system is established. It is thought that if desiccation can be reduced, undue wilting, which allows the plants to come in contact with the hot soil, can be prevented and a better stand obtained.

Waxing tests were conducted in the horticultural greenhouse at Iowa State College during the winter of 1937-38. Attempts were made to determine the concentration of wax emulsion that could be safely applied to tomato plants and the resulting effect on desiccation. The material used was patented by the Michigan State College and is manufactured and sold by the Dow Chemical Company under the trade name "Dowax". The concentrate was emulsified in tap water by agitating vigorously and strained through cheesecloth to make certain there were no lumps present. In this paper concentrations will be indicated as 1-4, 1-8, and so on. The first figure is the amount of "Dowax" and the latter the amount of water by volume.

Bonny Best tomato plants were used in these tests. The seeds were planted in flats and the small plants set in 3-inch pots. Tests were begun after the plants reached a height of about 10 inches. The method of applying the wax consisted of dipping the tops of potted plants into the emulsion for a few seconds and then shaking to remove the excess liquid.

It was found that an emulsion consisting of 1 part "Dowax" to 8 parts water could be safely applied without burning the plants. Stronger concentrations burned small spots within 48 hours, especially around the margin of the leaves. This test was repeated eight times during the year in the greenhouse. In preliminary field tests at Texas Substation No. 19, Winter Haven, Mr. C. R. Riecker found during the summer of 1938 that this (1-8) concentration did not burn tomato plants under field conditions.

Loss in weight of potted tomato plants was used as an index of the value of the emulsion in reducing desiccation. The soil was saturated with water and the pot and surface of the soil sealed with melted paraffin so that all water lost had to be transpired through the foliage. No water was added during the test. The following treatments of individual plants were replicated four times in each test and the same experiment was conducted five times: check (untreated), 1 part "Dowax" to 4 parts water, 1-8, and 1-16. Each treatment was therefore tested on 25 plants during the spring of 1938. The pots and plants in the first two series of tests were weighed every other day while in the last three series they were weighed daily. The tests were concluded at the end of 8 days as the plants in all treatments were yellow, possibly due to cutting off air from the roots.

The average loss in weight of the 25 plants in each treatment, as outlined above, is shown in Fig. 1. It is obvious that all concentrations

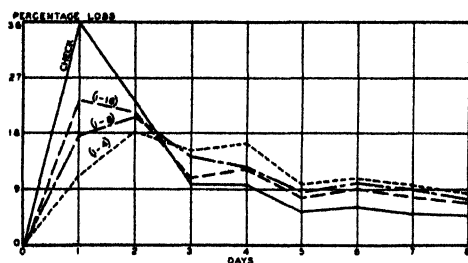


FIG. 1. Average loss in weight 25 potted tomato plants, five tests replicated four times.

used reduced desiccation. This was noticeable in the turgidity of the plants soon after treatment. The average loss in weight of the plants at the end of the first 2 days was as follows: check, 30.6 grams; 1-4, 10.1 grams; 1-8, 15.0 grams; 1-16, 18.6 grams. After the end of 4 days the plants in all treatments lost approximately the same amount.

In the last three series of tests the plants were weighed daily to determine more definitely the time desiccation took place. The percentage of the total weight lost occurring daily is shown in Fig. 2. It is shown that the loss in weight was greatest during the first 2 days. After that time the effect of the different treatments was not so noticeable.

The main benefit derived from covering the foliage with wax emulsion occurred during the first 2 days, and this protection was in proportion to the concentration used.

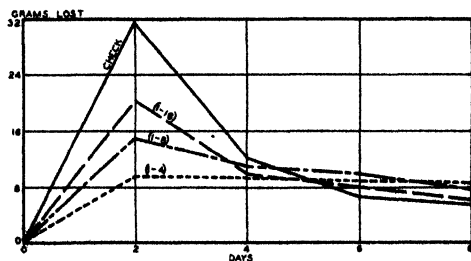


FIG. 2. Percentage of total loss in weight of potted tomato plants lost each day.

The 1-4 dilution injured the plants slightly but those treated with more dilute emulsions were uninjured. It appears that the 1-8 dilution reduced desiccation sufficiently to be of practical value during the first 2 days after treatment. Since this is the critical period following trans-

planting, these results are sufficiently indicative to justify field trials.

#### EFFECT OF WAX EMULSIONS ON APPLES

Preliminary tests have indicated that wax emulsions may be of benefit to apples in cold storage (2). An experiment was conducted to determine if "Dowax" emulsion would aid in the storage of apples at room temperature. Two varieties were used in this study. The Grimes Golden and Gano varieties were selected since the former has a light waxy covering and the latter a heavy wax deposit. Five uniform apples in each sample were dipped in the emulsion and placed on a paper plate. Each treatment was replicated two times, giving 15 apples in each. The following concentrations were used on both varieties: check (untreated), 1-1, 1-2, and 1-4. The test was started October 30 and the plates of apples were weighed weekly for 7 weeks.

The average loss in weight of the 15 apples in each treatment for the Gano variety is shown in Fig. 3. The results from both varieties

were so similar that the data obtained in the Grimes Golden tests are not presented. The emulsions reduced desiccation but there was no great difference between the concentrations tested. At the end of the 7 weeks the 15 Gano apples in each sample had lost in weight the following amount: check, 351.1 grams; 1-1, 187.7 grams; 1-2, 240.6 grams; 1-4, 249.5 grams. During

the same period the Grimes Golden apples lost: check, 480.2 grams; 1-1, 211.3 grams; 1-2, 294.2 grams; 1-4, 251.7 grams. The Gano apples were slightly burned by the emulsion. The untreated Gano apples were noticeably softer than those dipped in the emulsion, but there was little wrinkling of any at the end of 7 weeks. The Grimes Golden apples were severely burned by all concentrations of the emulsion. The degree of burning was in proportion to the strength of the emulsion with the check having the best appearance, though softer, at the end of the test. Wrinkling was most evident on the untreated apples and least on those covered with the 1-1 emulsion. The emulsions left an objectionable deposit which was visible to the end of the test. It is evident that the emulsions reduced desiccation but the storage life at room temperature was shortened.

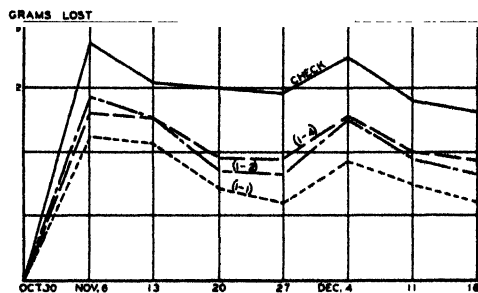


FIG. 3. Average loss in weight of Gano apples.

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## Evaluating Quality Changes in Certain Vegetables After Harvesting

By J. M. Lutz, U. S. Department of Agriculture, Meridian, Miss.

A NUMBER of chemical and physical indices have been used to evaluate quality changes in vegetables. Jones and Bisson (6) in a study of the garden pea after harvest showed that there was no essential change in the sucrose and starch content at 0 degrees C (32 degrees F) during a period of 7 days. At higher temperatures there was an increase in percentage of starch. Alcohol-insoluble solids, water-insoluble solids, and total solids have been used in evaluating quality of canned peas. Kertesz (9) found that the alcohol-insoluble-solids method was very satisfactory and was more accurate than the water-insoluble-solids or total-solids method. Jodidi (8) suggests a method of determining maturity of raw peas for canning based on specific gravity which is claimed to possess rapidity, accuracy, and simplicity. Martin *et al.* (10) recently reported that a machine known as a "tenderometer" can be used advantageously in the evaluation of the quality of raw peas as received at the canning factory.

In the case of asparagus, Bisson, Jones and Robbins (1) show that after harvesting, there is an increase in crude fiber and degree of lignification which is reflected in the toughness of the spears. There also was a loss in reducing substances and total sugars during storage. All of these changes were especially pronounced at the higher temperatures, whereas at 33 degrees F they were very slight. Culpepper and Moon (5) found in studying the quality of different portions of the asparagus shoot that resistance to pressure was closely associated with quality, the portions having the best quality generally also had the lowest pressure test reading.

Parker and Stuart (11) found that in snap beans sucrose increased more during warm storage than during cold storage. They state that "The carbohydrate data would indicate that a short storage period should improve the quality of snap beans, providing that the sucrose content is an important factor in determining quality."

One of the chief objects of all these physical and chemical methods is to determine an easily measured factor that is correlated with the palatability of the products for human consumption. Cooking the fresh products and making organoleptic tests would aid in accomplishing this purpose and if convenient, would probably be highly desirable in determining such characteristics as flavor, texture and color of the cooked product. Several workers have done this in making quality studies on vegetables. In studying after-harvest changes, this method has several obvious limitations. Probably the most important of these is that a person's standard of judgment might vary during the interval between the beginning and the end of the storage period. Thus, a sample of peas may receive a high rating both at the time of harvest and after storage for several days. Unless the observer sampled both lots at the same time and compared one with the other, he could not be certain whether changes in quality actually took place. Another limitation in

determining quality of vegetables by cooking and then sampling is the difficulty frequently encountered in securing a satisfactory panel of judges at all times during the course of an experiment. Still another drawback is that rush of work frequently makes it difficult to find time to cook the samples and judge them. Some method of preserving the sample for future observation is obviously desirable.

Freezing the vegetables being studied after they have been subjected to the various after-harvest treatments and then cooking them after several days or even after several months freezing storage has been found to be a very satisfactory method of avoiding the difficulties enumerated above. When such samples are cooked after freezing storage, they possess essentially the same characteristics which they had if cooked at the time they were frozen. They can be cooked whenever it is convenient to do so and all the samples of a given experiment can be cooked and compared with each other. Thus, samples taken at the time of harvest as well as at intervals during the storage period can be observed at the same time.

### METHODS

The vegetables were washed and prepared for freezing in the usual manner. Peas were shelled; the ends of the snap beans were snipped off and the remainder cut into segments 1-inch long; the asparagus was cut to 4½-inch lengths in 1937 and 5-inch lengths in 1938 by removing the butts these distances from the tip. After this preparatory treatment the products were blanched in boiling water, cooled immediately in cold water and then placed in containers which were moisture tight but not necessarily airtight. Except in the case of the 1935 peas which were frozen and stored at 15 degrees F, the freezing and storage temperature for the frozen products was 2 degrees F. The individual containers were spread out in the freezing room and subjected to rapid air circulation until they were frozen. The peas were blanched 1½ minutes in boiling water, the snap beans 3 minutes and the asparagus 4 minutes. The 1935 peas were examined 3 days after the end of the after-harvest treatment. The other products were examined after 5 to 10 months freezing storage.

The vegetables were cooked on electric heaters. A definite weight of product (150 grams) was cooked with a definite volume of liquid. The cover was removed from the cooking utensil as soon as the liquid started to boil. At the end of the cooking period, only a small amount of water remained. For peas and beans a 1 per cent salt solution was used, while for asparagus an 0.8 per cent solution was found to be more desirable. Three hundred cubic centimeters of liquid and 20 minutes boiling were used with asparagus and beans, while with peas 250 cubic centimeters of liquid and 12 minutes boiling time were used. The methods of freezing and cooking the products described herein were used to secure uniformity of treatment. Other methods of preparing the products such as the addition of butter to the cooked vegetables might result in better products but it was felt that such treatment might mask the flavor.

A numerical system was employed in grading the products. The

figure 1 denotes highest excellence, 1½ to 4 cover the range from very good through good to fair or just acceptable, and ratings of 4½ or higher figures indicate increasing degrees of unacceptability.

The sugar content was determined on alcohol-preserved samples of shelled peas and finely cut beans by the Quisumbing-Thomas method, the cuprous oxide being determined by the volumetric permanganate method.

Pressure test data on asparagus were obtained by determining the grams pressure required to puncture the spear 5 inches from the tip with the end of a wire 0.035 inch diameter. Thirty spears constituted a sample.

### RESULTS WITH PEAS

The results obtained with peas which are given in Table I are largely self-explanatory. The peas were stored in the pods but the samples for analyses were shelled after the storage periods indicated. The analyses are on these shelled peas. Although at 32 degrees F the percentage of sugar remained fairly constant in the case of Laxton Superb and showed a slight increase with the other two varieties, the quality decreased slightly in all cases at this temperature. This decrease in quality was associated with the length of the storage period. After 9 days at this temperature, which represents the approximate length of time that is required to transport peas from the pacific Coast to Eastern markets, the decrease in quality was only slight and if it had not been possible to make a direct comparison between peas at the time of harvest with those after this period of storage, it would doubtless have been concluded that no change in quality had occurred, since both lots received a high rating. Even after 34 days storage at 32 degrees, the peas were well within the range of acceptability and only when compared with peas frozen at the time of harvest could the degree of change in quality be accurately ascertained. At 36 and 40 degrees, changes in quality took place more rapidly than at 32 degrees. Brown (2) states that a lot of peas kept in cold storage 40 days still had excellent flavor when cooked. According to the results reported herein, peas held this long might still have good flavor, but would probably be inferior to peas cooked at the time of harvest. Jamison (7) concluded on the basis of chemical analysis which he confirmed by eating tests, that no appreciable lowering of the eating quality of peas took place at 32 degrees in 15 days. It is possible that if he could have compared the two samples at the same time a slight change in quality might have been observed. The results reported above which indicate that changes in quality of peas can occur at 32 degrees confirm those of Campbell and Diehl (3) who found that the quality rating of frozen pack peas prepared from material stored in the pod only 7 days at 32 degrees was rated "fair-tough-still sweet-some bitterness." Peas at the time of harvest and those held 5 days or less were rated as "good."

### RESULTS WITH BEANS

On a fresh weight basis there was a slight increase in the sugar content of snap beans held 4 days at 32 and 40 degrees F, a slight

TABLE I—COMPOSITION AND QUALITY OF PEAS AS INFLUENCED BY STORAGE

Storage Temperature (Degrees F)	Days	Alcohol- Insoluble Solids	Dry Weight	Total Sugars (as Dex- trose)	Total Sugars on Dry Weight Basis	Quality after Cooking (After Freezing Storage)		
		(Per Cent)	(Per Cent)	(Per Cent)	(Per Cent)	Color	Texture	Flavor
<i>Laxton Superb (1935)</i>								
Time of harvest	0	18.94	25.19	3.07	12.19	1½	1½	1½
32	9	21.33	27.54	3.34	12.13	2	2	2
36	9	23.09	28.44	2.69	9.46	2½	2½	2½
40	9	25.15	29.84	2.11	7.07	3	3½	3½
<i>Thomas Laxton (1937)</i>								
Time of harvest	0	10.91	19.41	5.20	26.79	1	1	1
32	20	11.60	21.34	6.31	29.57	2	2	1½
32	34	11.65	21.79	6.47	29.69	2½	2½	2½
<i>World Record (1937)</i>								
Time of harvest	0	10.38	19.44	5.46	28.09	1	1	1
32	9	9.85	20.24	6.51	32.16	2	1	1½
32	20	10.40	21.55	7.02	32.58	2½	2½	2½
32	34	11.36	22.79	7.35	32.25	3	3	3½
40	9	11.78	21.39	5.89	27.54	2	2	2

decrease in 2 days at 83 degrees and a marked decrease in 4 days at this temperature (Table II). Under all these conditions there was a decrease in the quality rating. On the basis of these data, it does not appear that sugar analysis alone can be used as an accurate index of quality in snap beans under all conditions. Culpepper (4) reports somewhat similar results in a study of the maturity of snap beans. He found that beans 25 days old from bloom had better quality when cooked than those that were 15 days old, even though the latter had a higher sugar content.

TABLE II—COMPOSITION AND QUALITY OF ASGROW STRINGLESS GREEN POD SNAP BEANS AS INFLUENCED BY STORAGE (1938)

Storage Temperature (Degrees F)	Days	Alcohol-Insoluble Solids (Per Cent)	Dry Weight (Per Cent)	Total Sugar (as Dextrose) (Per Cent)	Total Sugar on Dry Weight Basis (Per Cent)	Quality After Cooking (After Freezing Storage)		
						Color	Texture	Flavor
Time of harvest	0	6.46	10.42	2.52	24.18	2	1½	1½
32	4	7.68	12.05	2.61	21.66	2½	2	2½
40	4	7.58	11.98	2.79	23.29	2½	2	2
Room (83 degrees)	2	8.13	12.30	2.36	19.19	2½	2	2
Room (83 degrees)	4	8.58	12.37	1.94	15.68	3	3	2½

## RESULTS WITH ASPARAGUS

The asparagus used in these experiments was stored on wet moss unless otherwise indicated. The object of the experiment with the asparagus harvested May 10, 1937 was to determine the influence of various treatments that might be encountered by asparagus in retail stores and in the household. All of the asparagus in this experiment was held for 4 days at 50 degrees F on wet moss. Treatment 4 represents the asparagus at the time of removal from this condition. Treatments 5 and 7 were held for 6 and 24 hours, respectively, at room

temperature (76 degrees) after removal from 50 degrees. Treatments 6 and 8 were held on wet moss at this temperature, and in Treatment 9 the butts were placed in water during the holding period at room temperature. All of the asparagus in 1938 was held for 6 hours on wet moss at room temperature after removal from storage. This period probably represents the minimum interval that would occur commercially between removal from storage or transit conditions and cooking.

Culpepper and Moon (5) found in studying the quality of different segments of the asparagus stalk for canning that the portions with the highest pressure test was poorest in quality and conversely, the portions with the lowest pressure tests were highest in quality. Similar results have been secured in this laboratory in correlating quality for freezing, and pressure test, with different segments of the asparagus spear. However, it can be noted from Table III that with the possible exception of the asparagus harvested May 1, 1937, there was apparently no correlation between pressure test and quality of asparagus as influenced by storage. It can also be noted that there was no apparent change in quality during the first 10 days storage at 32 degrees F and only slight change at 14 days. After 21 and 28 days storage there were significant changes in quality. Due to difficulty with the cold storage plant, the temperature during the last 3 days of Treatment 14 was 40 degrees F instead of 32 degrees, thus perhaps accounting for some of the change in quality between the 14- and 21-day period. The results obtained with the asparagus harvested May 10, 1937 suggest the desirability of using asparagus as soon as possible after removal from storage or transit conditions, and that if it is necessary for the product to remain at room temperature for any length of time, it would be desirable to keep the butts of the spears on wet moss or in water.

TABLE III—PRESSURE TEST AND QUALITY OF ASPARAGUS AS INFLUENCED BY STORAGE CONDITIONS

Treatment	Pressure Test (5 Inches from Tip) (Grams)	Quality After Cooking (After Freezing Storage)		
		Color	Texture	Flavor
<i>Harvested May 1, 1937</i>				
1. None—Time of storage . . . . .	239	1½	2	1½
2. 28 days at 32 degrees F. . . . .	273	3½	3	3½
<i>Harvested May 10, 1937</i>				
3. None—Time of storage . . . . .	252	2	2	1
4. 4 days at 50 degrees F. . . . .	223	2	2	2
5. 4 days at 50 degrees plus 6 hours room temper- ature (76 degrees), dry . . . . .	214	2½	2½	2
6. 4 days at 50 degrees plus 6 hours room temper- ature (76 degrees), on wet moss. . . . .	237	2	2½	2
7. 4 days at 50 degrees plus 24 hours room temper- ature (76 degrees), dry . . . . .	217	3½	3	3
8. 4 days at 50 degrees plus 24 hours room temper- ature (76 degrees), on wet moss. . . . .	236	2½	3	2½
9. 4 days at 50 degrees plus 24 hours room temper- ature (76 degrees), in water. . . . .	232	2½	2½	2
<i>Harvested April 26, 1938</i>				
10. None—Time of storage . . . . .	209	1½	1½	1½
11. 4 days at 32 degrees F. . . . .	214	1½	1½	1½
12. 10 days at 32 degrees F. . . . .	219	1½	1½	1½
13. 14 days at 32 degrees F. . . . .	200	2	2	2
14. 21 days at 32 degrees F. . . . .	219	2½	2½	3



## SUMMARY AND CONCLUSIONS

It is evident from the results presented in this report that the chemical and physical determinations used in this work cannot always be relied upon to give accurate information on characteristics such as color, texture and flavor of certain vegetables after cooking as influenced by after-harvest treatment of the products. In order to make direct comparison of vegetables in experiments such as those involving determination of quality before storage and at intervals during storage, it is suggested that the products be frozen (after proper preparatory treatment) and stored at freezing temperatures until they are cooked. This method is of course applicable only to vegetables that can be frozen successfully and would not, therefore, be applicable at present to such products as tomatoes. This method is not suggested as a substitute for chemical and physical methods in exactly evaluating physiological changes but rather as a supplement to them when it can be used, since it furnishes a means of demonstrating whether or not changes detected by precise analytical methods have any practical significance from the standpoint of the consumer.

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# The Effect of Temperature on Splitting of Carnations

By ADOLPH J. SZENDEL, *Cornell University, Ithaca, N. Y.*

THIS paper presents a summary of the results obtained in experiments which were conducted over a period of 3 years in the Department of Floriculture and Ornamental Horticulture at Cornell University on splitting of carnations.

The plants were grown in compost soil in flats or in 7-inch pots. Low temperature studies were carried out in the greenhouse with temperature ranging from 40 to 50 degrees F or in the refrigerators at a temperature of 36 degrees F. The refrigerator temperature increased to 48 degrees F in the presence of light. Light was obtained from a 2500 watt mazda bulb from 8 a.m. to 5 p.m. producing a length of day of 9 hours, simulating winter conditions.

The light intensity as measured with a Weston Illumination Meter at the top of the plants varied from 800 to 1200 foot-candles. The high temperature treatments were carried out in a section of the greenhouse with temperatures ranging from 75 to 85 degrees F. The results and more detailed information are given in the following tables.

Experiment I was to determine the effect of low, medium and high temperatures upon splitting. The temperature fluctuations were started February 9, 1938 and continued to April 15. Ten plants of the variety *Sophelia* were grown one in a 7-inch pot. The results (Table I) show the percentage of flowers with split calyces increased as the temperature was reduced. The number of petals per flower increased as the temperature decreased.

TABLE I—THE EFFECT OF LOW, MEDIUM AND HIGH TEMPERATURES ON SPLITTING

Temperature Range (Degrees F)	Number Flowers Cut	Splits (Per Cent)	Average Number Petals
40 to 50	15	78.3 $\pm$ 4.36	71.5 $\pm$ 0.93
50 to 60	29	22.8 $\pm$ 6.83	68.8 $\pm$ 2.23
60 to 70	51	10.6 $\pm$ 2.38	68.6 $\pm$ 1.31

Experiment II was to determine the effects of a few days of low temperature upon splitting. Plants of the variety *Spectrum Supreme*, grown one plant to a 7-inch pot, were used. November 15, 1937 all plants were placed in the refrigerator. Four plants were removed from

TABLE II—THE EFFECT OF LOW TEMPERATURES ON SPLITTING

Treatment	Number Days Under Treatment	Number Flowers Cut	Splits (Per Cent)	Average Number Petals
Control (40 to 50 degrees F).	Continuously	21	13.5 $\pm$ 3.60	60.2 $\pm$ 2.12
Refrigerator (36 to 48 degrees F) . .	14	21	28.9 $\pm$ 1.93	65.0 $\pm$ 1.13
	30	22	47.8 $\pm$ 3.11	68.3 $\pm$ 1.45
	45	15	50.4 $\pm$ 4.13	68.0 $\pm$ 1.27
	75	11	79.2 $\pm$ 8.42	100.3 $\pm$ 5.65

the refrigerator after 14, 30, 45, and 75 days and placed in the greenhouse at a temperature of 40 to 50 degrees F. The check was grown continuously in the greenhouse.

The last observations were made April 30, 1938. The results (Table II) show that low temperature increased the number of petals and the percentage of split calyces.

Experiment III was made to determine the effect of short periods of high temperature on splitting. The plants were grown at a temperature of 40 to 50 degrees F excepting while at the high temperature. Plants were grown as in experiment II. The leaves at the tip of the shoots soon bent downward after the temperature was increased and it was possible to ascertain if the bud had formed previous to the treatment. The results (Table III) were divided, depending upon the time of bud formation with regards the beginning of the treatment.

High temperature treatment for a period of 14 or more days greatly reduced the percentage of flowers with split calyces. Flower buds formed during the period at high temperature did not produce split calyces.

TABLE III—THE EFFECT OF HIGH TEMPERATURE ON SPLITTING

Treatment (75 to 85 Degrees F)	Flowers Formed Before Treatment			Flowers Formed During Treatment			Flowers Formed After Treatment		
	Flow- ers Cut	Splits	Average Number Petals	Flow- ers Cut	Splits	Average Number Petals	Flow- ers Cut	Splits	Average Number Petals
40 to 50 Continuously		—		13	61.5	70.8 ± 2.73	—	—	
A—7 days	7	7	79.1 ± 2.10	8	0	50.9 ± 2.08	2	1	73.5 ± 1.06
B—14 days	9	1	63.1 ± 1.41	5	0	31.8 ± 0.96	2	1	68.0 ± 5.93
C—30 days	6	0	70.5 ± 2.00	11	0	38.5 ± 1.13	0	—	
D—76 days	9	0	76.2 ± 2.83	14	0	38.5 ± 1.76	0	—	
Total	31	8		38	0		4	2	
Check excluded		25.8%			0.0%			50.0%	
Mean		—	72.2 ± 2.37	—	—	39.9 ± 2.68	—	—	70.7 ± 2.78

Experiment IV was carried out to determine the effect of one night of low temperature at various intervals upon splitting. Plants of the variety Spectrum Supreme were grown in flats. Two flats of four plants each were used in each experiment. The treatments were started November 3, 1936 and were continued to April 1, 1937.

The plants were grown in greenhouses at temperatures of 50 to 60, 60 to 70, and 70 to 80 degrees respectively. They were placed in a 40 to 50 degree house every night, every seventh night or every fourteenth night and returned to the higher temperature the following morning.

The results (Table IV) show that splitting was greatest when the night temperature was reduced twice each month. Plants grown at high day temperatures and low night temperatures did not produce as great a percentage of flowers with split calyces as those grown at lower day temperatures. Plants grown at high temperatures and occasionally given a low night temperature produced more splits than those grown at a continuous low temperature.

TABLE IV—THE EFFECT OF ONE NIGHT OF LOW TEMPERATURE ON SPLITTING

Frequency of Low Temperature Treatment	Total Number of Flowers Cut	Percent of Splits at Temperatures of			Average Per Cent Splits for Treatment
		50 to 60 Degrees F	60 to 70 Degrees F	70 to 80 Degrees F	
Every night . . . . .	53	23.1	13.3	16.0	17.5-1.97
Every 7th night . . . . .	62	18.2	26.9	35.7	26.9-3.41
Twice a month . . . . .	82	39.3	38.9	44.5	40.9-1.22
Average percent of splits for groups . . . . .	—	26.9 ± 4.30	26.4 ± 5.01	32.1 ± 5.67	28.4 ± 2.58
Total number of flowers cut . .	197	63	77	57	

## SUMMARY

1. The lower the temperature the higher the percentage of splits.
2. The longer the heat treatment the lower the percentage of splits in flowers formed before or after a short period of high temperature. No splits were found among the flowers formed during the heat treatment.
3. A prolonged period of extremely low temperatures (36 to 48 degrees F) increased significantly the average number of petals.
4. Heat treatment reduced significantly the average number of petals in flowers formed during the heat treatment. It did not affect the average number of petals in flowers formed before or after the heat treatment.
5. A short low temperature period (one night) occurring at great time intervals increased significantly splitting as compared with frequent low temperature treatments. This splitting is explained by a circumferential contraction of the calyx due to the change of temperature in question.
6. The critical stage of bud development, associated with splitting was when the bud started to open and expose the petals. No splitting occurred in small or in fully developed buds.

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## Growth Studies in Tulips

By R. L. PRYOR, *U. S. Horticultural Station, Beltsville, Md.*

**V**ERY little information is available on the seasonal growth of tulip bulbs in the United States. In order to furnish information preliminary to some proposed fertilizer experiments, the following studies were conducted last year at the United States Horticultural Station, Beltsville, Maryland, and are being continued.

The variety used was Pride of Haarlem. The bulbs ranged in weight from 6 to 28 grams. Each individual bulb was numbered, weighed, and placed in a separate container. There were 20 lots of 50 bulbs each, and all were planted on October 16, 1937, in rows 3 feet apart with 1 foot between bulbs. The bulbs were dug in lots of 50, the first being removed from the soil on November 16, 1937. Thereafter lots were dug at 2-week intervals, or as near that as weather conditions would permit.

Fig. 1, in the form of a graph, shows the progressive increase or decrease in the weight of the bulbs from planting to planting time the following year. It is based on the mean weight of each lot of 50 bulbs expressed in percentage increase or decrease over the original planting weight. These weights were obtained after the tops and the roots had been removed from the bulbs. The percentages of increase or decrease are on the perpendicular axis and the times of digging are on the horizontal axis.

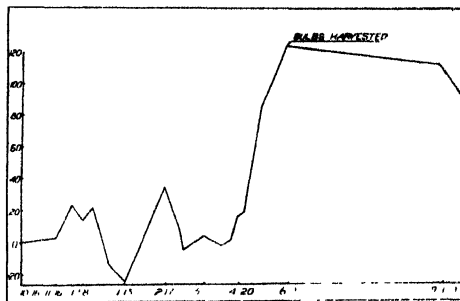


FIG. 1. Bulb development of tulip, variety Pride of Haarlem, 1937-38.

The zero point for each date is the mean weight of the lot of 50 bulbs at the time of planting, and the increase or decrease shown is for that lot of 50 bulbs only.

The first four lots dug showed an increase over their respective planting weights; however, the fifth and sixth showed a decided loss in weight from those at the time of planting. When the sixth lot was dug on January 13, the bulbs had all begun to send up sprouts, although there was no growth above ground. At this time the flower stems of the 50 bulbs averaged 2 centimeters in length above the nose of the bulb. The outermost scales were soft and lacked turgidity, indicating a loss of stored food. The next lot of 50 was dug on February 17, and at this time the bulb units had increased in weight considerably from the time of planting. There was an average of 6 centimeters of top growth above ground, but none of the flower buds had emerged from the leaves. The bulbs themselves showed considerable change since the previous digging on January 13. They all appeared firm, indicating the

new bulbs had increased in size sufficiently to give a rigidity to the entire bulb. The next lot was dug on February 29, and while there was an increase over the weight at planting, the percentage increase was not as great as it was on February 13. The next lot was dug on March 3, and showed a loss from the original weight.

The bulbs began to bloom on April 6 and continued until April 20. During the period as shown by the data on March 21, April 6, 14, 20, and 26 when the plants were blooming, there was little or no increase in bulb weight. The lot dug on May 3 after blooming showed a very marked increase in weight over the previous lot dug on April 26. On May 11, just 8 days later, the bulbs had gained 85 per cent in weight, and when finally harvested on June 2 they had gained 124 per cent in weight. The lot that was weighed on June 2 was placed in storage with three remaining lots harvested at the same time. On September 9, two were weighed and both showed considerable increase over their original weight. On September 28 the remaining two lots were weighed and both showed a good net increase, but the lot that was previously weighed on June 2 had lost weight so that it showed only a total increase of 85 per cent as compared to 124 per cent in June. This may represent a loss of moisture content.

From the above data it appears that there are two exhaustion periods in the tulip bulb during its growing period. The first is when the tops and flower stems begin to elongate, the old bulb to disintegrate, and the new bulbs are developing. The second is while the tops are elongating rapidly and during maturation of flowers. It also appears that the main growth takes place after blooming. This is probably due to the rapid elaboration of storage material in the plant.

## Time of Bloom of Double and Single Stocks

By R. L. PRYOR, *U. S. Horticultural Station, Beltsville, Md.*

**D**URING the past 3 years, at the United States Horticultural Station, Beltsville, Maryland, a group of experiments has been under way concerned with the problem of doubleness in stocks. Most of this work has been centered around the eversporting types which produce a slight excess of doubles over singles.

According to observation by Saunders(1), the double flowered plants bloom before the singles. In order to secure some data on this question, the following experiment was conducted at Beltsville during the past year.

Seed of 24 inbred lines of Column Lavender stocks was sown August 15, 1937, and on September 8, 1937, the seedlings were transplanted to flats in which they were allowed to bloom. The temperature at which they were grown was within the range of 60 to 70 degrees F. The plants were considered in bloom when the first flower was open.

Seed for a second test was planted on January 6, 1938, and the seedlings were transplanted to flats on January 30, 1938. These plants were also grown at a temperature range of 60 to 70 degrees F.

Since both lots of plants behaved in a similar manner in regard to blooming, the data was combined and is shown as a graph in Fig. 1.

The open space or left column represents the percentage of doubles of the whole population blooming at the time the first reading, while the black column represents the percentage of singles of the whole population blooming at the time of the first reading, and so on through the 12 readings.

The readings were made at approximately 3-day intervals, and at each reading the percentage of the total is given at the end of each column. The total number of plants is also inscribed in each column.

On the first reading there were 1,057 plants actually in bloom. Of these 830 were doubles and 227 were singles. In the second reading 682 were doubles and 523 were singles. The total amounted to 2,661 doubles and 2,508 singles. The data on this graph does not show the actual number of doubles, because a correction was made for the excess over the singles.

Since the inbred lines may have varied as to time of bloom, the first graph may not show as great a difference in favor of the doubles as



FIG. 1. Time of bloom of stocks; line 120 (1938)

is shown in Fig. 2. This represents the data from a single inbred line composed of 236 plants.

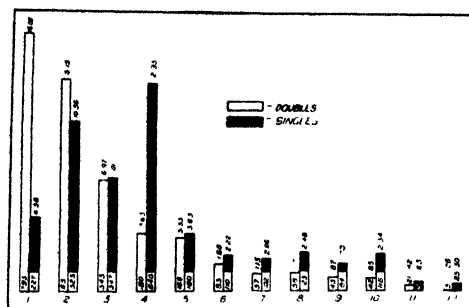


FIG. 2. Time of bloom of stocks, 24 combined inbred lines.

of doubles than singles, the number of doubles has been corrected to compensate, and on this basis the count for the first 6 days is 82 doubles to 26 singles.

The above data show that with the lines of stocks used and under these conditions, double flowered plants bloom in advance of the singles.

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The left or open column represents the percentage of doubles blooming at a given date, while the black or solid column represents the percentage of singles blooming on the same date. It will be noted that in the first 6 days, of the 111 plants that bloomed, 85 were double and 26 were single. Since the final count of the entire population showed a higher amount



# A Study of Flowering Rose Shoots with Reference to Flower-Bud Differentiation

By ALEX LAURIE and PAUL F. BOBULA, *Ohio State University, Columbus, Ohio*

THE purpose of this work was to determine the time at which flower-bud differentiation first becomes evident in shoots developing from buds on flowering wood. The ultimate aim is to ascertain the time at which artificial illumination might be applied to pinched roses in the winter to reduce the percentage of blind shoots that usually develop from flowering wood under the reduced day-length and light intensity prevailing during the winter months.

## MATERIALS AND METHODS

On September 22, 1938, flowering shoots of the variety Better Times were cut back so that apparently dormant axillary buds were made to assume a terminal position. At this time each of the selected axillary buds was assigned a number and tagged.

Buds were collected at intervals of 14, 15, 16, 17 and 20 days after the selected axillary buds had been made to assume a terminal position. Immediately after collection, the selected axillary buds, or the terminal buds of shoots developed from these axillary buds, were killed in "universal fixative". The collected buds were then prepared for study by the paraffin method as outlined by Chamberlain (1). The slides were stained with safranine.

The age of a particular axillary bud, or of the terminal bud of a shoot developed from an axillary bud, was figured from the time the axillary bud was made to assume a terminal position.

## RESULTS

Of the 80 collected buds, 71 were successfully prepared for study. The results of the study are as follows:

Age When Removed (Days)	Number Buds Examined	Average Shoot Length (Inch)	Buds Showing Differentiation (Per Cent)	Stages of Differentiation Present
14	3	0.41	100.00	All buds with sepal primordia
15	12	0.00	0.00	All buds vegetative
16	15	0.37	80.00	3 buds vegetative 6 buds in first stage of differentiation 4 buds with sepal primordia 2 buds with sepal and petal primordia
17	28	0.24	60.7	11 buds vegetative 8 buds in first stage of differentiation 8 buds with sepal primordia 1 bud with sepal and petal primordia
18	11	0.33	72.7	3 buds vegetative 2 buds in first stage of differentiation 4 buds with sepal primordia
20	2	0.00	0.00	2 buds with sepal and petal primordia All buds vegetative

## DISCUSSION

In roses the order in which the flower parts differentiate is as follows: sepals first, petals second, stamens third and pistils last. The first evidence of flower-bud differentiation is a broadening and thickening of the floral axis (2).

The data indicate the following: (a) flower-bud differentiation did not occur at the same rate in all buds growing on flowering wood; (b) in the more actively growing buds, differentiation occurred at approximately the same rate; (c) the first evidence of differentiation was found in buds 16 to 18 days after they had been made to assume a terminal position; (d) sepal primordia were present in buds which had been in a terminal position for 14 to 18 days; and (e) sepal and petal primordia were present in buds which had been in a terminal position for 16 to 18 days.

## CONCLUSIONS

A study was made of the development of buds growing on flowering rose shoots of the variety Better Times. It was found that flower-bud differentiation had occurred in buds which had grown actively for 14 to 18 days after they had been made to assume a terminal position. Since the data in this paper show that flower-bud differentiation occurs very early in shoots developed from actively growing buds on flowering wood, it seems probable that artificial illumination should be applied immediately upon pinching to be effective in reducing the high percentage of blind shoots that are usually formed from flowering wood during the winter months.

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# Gravel and Cinder Culture of Greenhouse Flowering Plants

By ALEX LAURIE and ARNOLD WAGNER, *Ohio State University,  
Columbus, Ohio*

**D**URING the past 2 years the Division of Floriculture of the Ohio State University has carried on extensive experiments with nutrient solution culture of plants. An attempt has been made to make it applicable to the commercial greenhouse florist. We have had three aims in mind: (a) to simplify the entire system, including solutions, routine work, and so on; (b) to ascertain the best solutions for winter and summer conditions; and (c) to determine the best medium (various gravels, cinders, and haydite).

Since we are steadily increasing our facilities for experimentation with gravel and cinder culture, this present report should be taken as a progress report of the work done up to this time.

The advantages of gravel-cinder culture appear to be: (a) Greatly reduced labor (no watering, no weeding, no cultivation, no fertilizing, no changing of soil); (b) type of growth can be controlled by increasing or decreasing concentration of solution and by varying the ratios of the constituents; (c) largely automatic; (d) absence of a large number of the soil-borne pests and diseases; (e) better quality of flowers; and (f) increase in production of roses.

## THE AUTOMATIC SUBIRRIGATION SYSTEM

New waterproof concrete benches with no drainage holes in the bottom as made by the Winandy Construction Company, Richmond, Indiana, are the most ideal to use. Otherwise, old wood benches must be waterproofed with roofing material and a pure asphalt paint. Recently a liquid asphalt emulsion similar to that used in road work has been used at Ohio State successfully, thus saving considerable time and trouble in melting the solid asphalt. A concrete tank under the bench contains the nutrient solution. A time clock automatically operates a centrifugal pump which forces the water through an inverted eaves-trough running the entire length of the bench at the rate of 20 gallons per minute. The solution is allowed to come up within an inch of the top surface of the medium and drains back by gravity into the cistern. A valve should be so located in the line so as to make it possible to expel the solution into a drain. Another valve should make it possible to empty the solution from the bench to the outside drain.

## MEDIA

Several types are now being tried, including soft coal cinders, silica gravel, local gravel (calcareous), crushed limestone, and Haydite. Haydite is a burnt shale and clay compound. Haydite appears to be desirable from the standpoint that it always has a constant composition. The "C" grade is recommended. Haydite is manufactured by the Hydraulic-Press Brick Company, South Park, Ohio. In general, it appears that calcareous gravels can be used just as well as silica

gravels, providing the alkalinity is gradually reduced to neutral reaction by sulphuric acid. Gravels should contain particles ranging from  $\frac{1}{8}$  to  $\frac{3}{4}$  inch screen to remove the finer particles and then the larger clinkers over 1 inch in diameter removed. No acid treatment previous to planting is necessary. Limestone has been used successfully for chrysanthemums, stocks and sweet peas. If fresh crushed limestone is used it will probably require about 2 months of the above mentioned acid treatment before the pH is lowered sufficiently. It has been found that a protective coating is soon formed around the limestone particle, thus preventing the limestone from completely dissolving away.

### SOLUTIONS

Of the various formulae tried, the WP formula produced the best growth on the majority of plants. This formula was originated by the Division of Floriculture at Ohio State University (1). Withrow's 2D, 2E, and 1E solutions were tried but proved inferior to the WP series (3). Most chemicals are of a commercial grade.

TABLE I—COMPOSITION OF THE WP FORMULA

Chemicals	Cost Per Pound (Cents)	Grams Per 1000 Gallons Water	Concentration in Millimoles	Millimoles of 2 WP Solution
KNO <sub>3</sub> —potassium nitrate	4	2032	6.27	12.54
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> —ammonium sulfate	2½	439	.86	1.72
MgSO <sub>4</sub> ·7H <sub>2</sub> O—magnesium sulfate	2½	2043	2.08	4.16
CaH <sub>2</sub> (PO <sub>4</sub> ) <sub>2</sub> ·H <sub>2</sub> O—monocalcium* phosphate (food grade)	8	1090	1.06	2.12
CaSO <sub>4</sub> ·2H <sub>2</sub> O—calcium sulphate	¾	4856	6.46	12.92

\*This should be of the "food grade", since it is imperative that the fluorine content be low.

The 2 WP solution is made by adding 440 grams or 15½ ounces of the WP formula to 20 gallons of water. The 2 WP solution may be used for all crops.

### 2 WP SOLUTION

	Parts per Million
NO <sub>3</sub> (including NH <sub>3</sub> )	1000
NH <sub>3</sub>	56
PO <sub>4</sub>	400
K	500
Ca	600
Mg	100

At the time of changing solutions, iron is added at the rate of 2.3 grams of FeSO<sub>4</sub> for 25 gallons of solution and manganous sulphate is added at the rate of 100 cubic centimeters of a  $\frac{1}{2}$  per cent solution for 25 gallons of nutrient solution. In some cases it may be necessary to add iron once or twice a week at the above rate.

### CHANGING OF SOLUTIONS

It has been found that better results can be obtained by changing solutions every 2 weeks for the first 3 months when the cinders or gravel are new and only once every month after the medium has had time to become thoroughly absorbed with the various nutrient ions. Indications are that solutions may be used as long as 2 or 3 months without changing, providing tests are made for nitrogen, phosphorus,

potassium, magnesium, and calcium at weekly intervals and suitable amounts added in case tests show low amounts present. Naturally this depends upon season of year and type of crop.

#### DIFFICULTIES ENCOUNTERED AND GENERAL POINTERS

1. *pH*. We have trouble by solutions becoming too acid. As a remedy NaOH is added to solutions. The pH of nutrient solutions for roses, stocks, sweet peas and other near-neutral or slightly alkaline crops should be maintained at pH 6.5 to 7.0. Practically all other crops should be maintained about pH 6.0 to 6.5. Gardenias grow best at pH 5.5 to 6. *The success of gravel culture depends to quite an extent upon maintaining a correct pH at all times.*

2. Iron and phosphorus must be checked regularly.

3. Algae growth can be controlled successfully by pumping the solution within 1 inch of the surface, and not flooding the surface.

4. Spray injury to roots due to selenium (Selocide) or thiocyanate (Lethane and Loro) sprays can be prevented by keeping the bench filled with tap water during time of spraying.

5. Sweet pea bud drop can be controlled by increasing concentration of solution.

6. Propagation of plants. Plants which must be grown from seed grow better if seed is sown in sand and fed with nutrient solution. Sweet pea seed can be sown directly in the bench. For plants propagated by cuttings, the ideal method is to allow the cuttings to become thoroughly rooted in an ordinary propagating bench in sharp sand and then plant directly to the gravel bench.

7. Extensive tests conducted here indicate that flowers produced by gravel and cinder culture keep just as well as those grown in soil.

#### RESULTS OF VARIOUS TESTS CONDUCTED AT OHIO STATE UNIVERSITY

*Growing Roses in Gravel and Cinders*.—The variety used was Better Times, started buds planted in February, 1938, and then built until July when the first roses were cut. The record includes the cut from then until October 15, a period of 3 months.

TABLE II—PRODUCTION TABLE—ROSES

Plot	Average Number of Flowers per Plant
Plot 1—Soil, normal commercial practice . . . . .	10.0
Plot 2—2 E solution, silica gravel . . . . .	14.5
Plot 3—2 WP solution, silica gravel . . . . .	16.5
Plot 4—2 W solution (no ammonia), silica gravel . . . . .	15.0
Plot 5—2 WP solution, fine grade silica gravel . . . . .	14.0
Plot 6—2 WP solution, cinders . . . . .	19.0

These records indicate that in every instance the gravel or cinder plots produced a greater number than soil, which in itself produced as well as could be expected since, based on 10 flowers for that period, a total expectation of over 20 per year may easily be secured. The best production was in cinders, followed by silica gravel with 2 WP solution. The solution was pumped through three times each day and changed weekly.

A grading table in per cent of various stem lengths was worked out and it was found that the highest percentage of shorts occurs in soil and likewise the highest percentage of 9- to 12-inch stems. The plots with 2 WP solution either in gravel or cinders gave the least shorts and a much greater percentage of the higher grades.

TABLE III—GRADING TABLE (PER CENT)

Plot	1	2	3	4	5	6
Shorts	13	11	4	3	7	2
9 to 12	48	33	20	14	19	10
12 to 15	19	28	31	23	24	24
15 to 18	10	17	22	25	28	22
18 to 21	7	6	14	19	12	24
21 to 24	2	5	6	9	6	12
24 to 30	1	—	2	6	4	6
30 to 36	—	—	1	1	—	—

*Results of Chrysanthemum Tests in Gravel Culture, Summer of 1938; Varieties, Silver Sheen and Firebird; planted, April 29, 1938:—*

Those planted in gravel culture were directly from the propagation bench, cuttings stuck April 1, 1938. Soil check plants were propagated March 7, 1938 (3 weeks before gravel culture plants) and planted out of 2½-inch pots. Solutions were changed every 2 weeks. They were pumped five times daily during the active period of growth and three times daily after buds were well developed.

Rating of various solutions (best to poorest): 1, 2 WP; 2, WP; 3, 2 D; 4, 2 W; and 5, soil.

Rating of various media (best to poorest): 1, silica gravel; 2, cinders; 3, limestone; 4, calcareous gravel; and 5, soil.

TABLE IV—PRODUCTION TABLE—CHRYSANTHEMUMS

Plot	Treatment	Firebird			Silver Sheen	
		Average Height in Bench (Inches)	Number Ounces Per Plant	Number Plants Required to Make 1 9-ounce Bunch	Diameter of Flower (Inches)	Stem Length (Inches)
1	Soil check	32	3.74	2.4	4½	39
2	2 WP—silica gravel pH 4—4.5	31	4.36	2.06	5	43
3	2 WP—silica gravel pH 6.5—7. Spray injury to roots (later recovery)	29	4.00	2.25	5	40
4	2 D—silica gravel	31	4.82	1.9	5	41
5	2 D—limestone	31	4.28	2.1	5	37
6	2 D—coarse local gravel (calcareous)	32	4.52	2	5	36
7	2 D—fine local gravel (calcareous)	30	3.42	2.6	5½	35
8	2 D—cinders insect attack	32	3.34	2.7	5	39
9	2 W—silica gravel (no ammonia)	30	4.2	2.14	5	38
10	WP—silica gravel	32	4.2	2.14	5½	42
11	2 WP—unmulched	31	4.0	2.25	5	40
12	2 WP—mulched with glass wool	33	5.92	1.52	5	40

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# The Effect of Different Fertilizer Ratios on Colonial, Creeping, and Velvet Bent Grasses<sup>1</sup>

By J. A. DEFRANCE, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

A STUDY of the response of certain fine turf grasses to fertilizer nutrients when closely clipped was started in September, 1932.<sup>2</sup> Some of the results based on a 5-year study are presented in this report. More detailed information and other results of this study will be given in a later publication. The grasses used were three popular bent grasses as follows: Colonial bent (*Agrostis tenuis*) native Rhode Island local grown seed; Creeping bent (*Agrostis palustris*) Washington strain—local grown stolons; Velvet bent (*Agrostis canina*) Piper strain—formerly United States Department of Agriculture, Bureau Plant Industry No. 14276—local grown stolons.

The object of the experiment was to determine the relative response of certain lawn and turf grasses to nitrogen, phosphorus, and potash as measured by relative growth and vigor; to study the influence of the different fertilizer ratios on the quality of the turf as measured by the color, fineness of leaf, and denseness of growth; and to study the influence of the different fertilizer ratios on the resistance of turf to weeds and diseases.

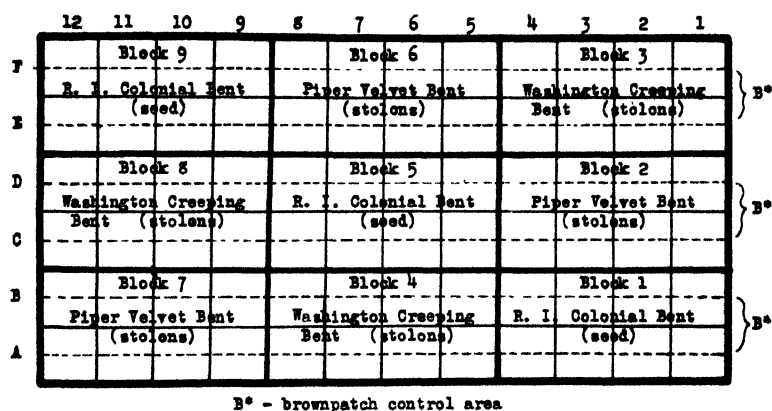


FIG. 1. General plan of fertilizer ratio test on three popular bent grasses.

Fig. 1 shows the general plan of the fertilizer ratio test on the three bent grasses. The grasses were planted in triplicate blocks, 20 feet by 40 feet. Each block was divided into eight plats each 10 feet by 10 feet (1/436 acre). The three blocks of each grass were planted systematically through the area in an attempt to overcome any

<sup>1</sup>Published by permission of the Director of Research as Contribution No. 543 of the Station.

<sup>2</sup>This work was initiated and executed until the spring of 1936 by H. F. A. North, former Assistant Agronomist.

heterogeneity of the soil. The different bent grasses were separated by paths of Chewing's fescue. Fig. 2 shows the detailed plan of the fertilizer ratio test. Each block has the plats in the same systematic arrangement and indicates the area that was treated for brownpatch control. This consisted of a strip 5 feet wide and 10 feet long in each plat.

	4	3	2	1	
B	High N 20-6-4	Standard 10-6-4	High K 10-6-8	Low K 10-6-0	Test for control of brownpatch
A	Low N 5-6-4	High P 10-12-4	Low P 10-0-4	Low P & K 10-0-0	
	4	3	2	1	

FIG. 2. Detail plan of fertilizer ratio test (Block 1).

The fertilizer ratios are designated as follows and were applied on the basis of approximately 1,500 pounds per acre or 34 pounds of the standard (10-6-4) fertilizer per 1,000 square feet during the season.

<i>Fertilizer ratio</i>	<i>Designation</i>
10-6-4	Standard
5-6-4	Low nitrogen
20-6-4	High nitrogen
10-12-4	High phosphorus
10-0-4	Low phosphorus
10-6-8	High potash
10-6-0	Low potash
10-0-0	Low phosphorus and potash

The nitrogen was obtained from sulphate of ammonia, nitrate of soda, and activated sludge in the proportions of 50, 20, and 30 respectively. The phosphorus was obtained from superphosphate and the potash from muriate of potash. It was thought desirable to employ a complete fertilizer and to use a combination of nitrogen sources rather than a single source.

It has been evident from other tests that comparatively more growth early and late in the season results from nitrate of soda as compared with sulphate of ammonia fertilization. Sulphate of ammonia was used as it has been found to inhibit to a great extent the development of certain weeds. Since a soil and sand mixture was to be used for top-dressing purposes rather than compost, activated sludge was included to replace this, in part. An added advantage is the fact that it tends to give a more uniform growth throughout the season and a more prolonged growth in the fall than does nitrogen in a mineral form.



Limestone was applied at the rate of 2 tons per acre prior to seeding as the original pH was found to be approximately 4.9 from tests of 60 samples taken from the area, and it was desired to have a pH of about 5.5.

Rhode Island Colonial bent was seeded at the rate of 2.2 pounds per 1,000 square feet or 100 grams per plat. The velvet and creeping bents were planted with stolons that were picked apart by hand from nursery grown rows at the rate of 1 bushel of stolons per plat (100 square feet).

Comparisons were made on the basis of the factors affecting quality as follows:

Vigor—Scale 1 to 5. Rapidity of growth. A rating of 1 is poor and 5 is excellent.

Color—Scale 1 to 5. Darkness of green. A light green does not rate as high as a rich dark green.

Texture—Scale 1 to 5. Fineness of the leaf blades.

Density—Scale 1 to 5. Amount of crowding together of the leaves.

Disease—Per cent of area affected.

Weeds—Time of labor required to remove.

Bent mixture—Percentage of bent grass other than the species planted.

Notes on the factor of color were taken monthly from April to October. Vigor, texture, and density were noted during April, June, August, and October. The percentage of diseased area was noted after new outbreaks developed. The percentage of clover and bent mixture was taken in May and September. Weeding was done in May, mid-summer, and autumn. In the tables the quality averages based on the scale of 1 to 5, for the season, were multiplied by 20 in order to express the ratings in per cent.

Mowing was done three times a week during the growing season at a height of  $\frac{1}{4}$  inch and the clippings were removed. Fertilizer was applied as follows: 30 per cent of total, April 1 to 7; 20 per cent, May 1 to 7; 20 per cent, July 1 to 7; and 30 per cent, September 1 to 7. Topdressing was made with sterilized soil and sand (4 to 1 mixture) at the rate of  $\frac{1}{5}$  cubic yard per 1,000 square feet and applied to all grasses in April, May, July, and September, and also to the creeping bent plats in June and August. Preventive treatment for disease such as brownpatch was made on one-half of each plat with applications of a mixture of  $\frac{1}{3}$  bichloride of mercury and  $\frac{2}{3}$  calomel at the rate of 2 ounces per 1,000 square feet and applied every 10 days from June 21 to September 1 making eight applications during the season. The whole section was treated with arsenate of lead in July, 1933, at the rate of 5 pounds per 1,000 square feet as no preseedling treatment had been made for grub control. Webworm treatment was applied in May, July, and September at the rate of 2 pounds arsenate of lead per 1,000 square feet.

In Table I is given the 5-year average (1933 to 1937) of vigor, color, texture, and density of Rhode Island Colonial, Washington creeping bent, and Piper velvet bent as affected by different fertilizer ratios.

TABLE I—FIVE-YEAR AVERAGE OF VIGOR, COLOR, TEXTURE, AND DENSITY.  
OF RHODE ISLAND COLONIAL BENT, WASHINGTON CREEPING BENT, AND  
PIPER VELVET BENT AS AFFECTED BY DIFFERENT FERTILIZER RATIOS

Fertilizer Ratio	Rating (Per Cent)			
	Vigor	Color	Texture	Density
<i>Rhode Island Colonial Bent</i>				
10-0-0	59	53	64	45
10-0-4	59	54	64	44
10-12-4	63	55	65	51
5-6-4	45	44	67	38
10-6-0	61	53	62	46
10-6-8	59	53	64	45
10-6-4	76	53	64	45
20-6-4	76	53	62	61
Average	60	53	64	46
<i>Washington Creeping Bent</i>				
10-0-0	45	47	53	45
10-0-4	45	46	53	44
10-12-4	47	48	54	45
5-6-4	35	38	55	35
10-6-0	45	49	52	47
10-6-8	44	47	52	46
10-6-4	45	48	53	46
20-6-4	60	61	55	61
Average	46	48	53	46
<i>Piper Velvet Bent</i>				
10-0-0	60	69	84	73
10-0-4	59	69	84	73
10-12-4	61	70	85	76
5-6-4	47	62	86	63
10-6-0	59	70	84	75
10-6-8	59	70	84	75
10-6-4	80	71	85	75
20-6-4	75	82	85	88
Average	60	70	85	75

The 5-year average of the vigor notes on the three species of bent grass treated with the different fertilizer ratios indicates that the most vigorous growth was a result of the high nitrogen (20-6-4) fertilizer where Rhode Island bent was given a percentage rating of 76; Washington creeping bent 60; and Piper velvet 75. The least vigorous turf occurred on the low nitrogen (5-6-4) plats where Rhode Island bent had a percentage rating of 45; Washington creeping bent 35; and Piper velvet bent 47. The second most vigorous plats were those receiving the high phosphorus (10-12-4) mixture. The addition of either 4 or 8 units of potash gave no increase in vigor. This would seem to indicate that nitrogen and phosphorus played the most important part in vigor as estimated by rate of growth and general appearance of the turf. On all the respective fertilizer ratio plats the rating of vigor was quite similar for Rhode Island Colonial and Piper velvet bent and both of these grasses were rated considerably higher than Washington creeping bent with regard to rate of growth.

The 5-year average of color was highest on the high nitrogen (20-6-4) plats and lowest on the low nitrogen (5-6-4) plats. There was apparently very little difference in color arising from the use of the other fertilizer ratios and it seems apparent that nitrogen is the only nutrient that influenced the color of the three grasses in this study as

the addition of phosphorus or potash had no beneficial effect. The plats of Piper velvet bent were in all cases rated higher than either Rhode Island bent or Washington creeping bent. Rhode Island bent was rated slightly higher than Washington creeping bent on all plats.

The averages of texture indicate that the finest textured turf of all three grasses was developed on plats receiving the 5-6-4 fertilizer or smallest amount of nitrogen and on the 20-6-4 plat of Washington creeping bent. The coarsest Rhode Island bent turf was on the high nitrogen and low potash plats, and with Washington bent the coarsest turf was on the low potash and high potash plats. There was very little difference in coarseness occurring on the different plats of Piper velvet bent. The highest ratings of texture were on the low nitrogen plats which was just the opposite from the highest ratings of color, density, and vigor which occurred on the high nitrogen plats.

The most dense turf occurred where the most nitrogen (20-6-4) was used and the least dense where the smallest amount of nitrogen (5-6-4) was applied. The high phosphorus plats of Piper velvet and Rhode Island bent were superior to all but the high nitrogen plats. The addition of phosphorus or potash to the other fertilizer plats did not seem to make any great difference so it appears that nitrogen is the governing factor of density.

Regarding vigor, color, density, and texture the 10-0-4 plats, in general, were not superior to the 10-0-0 plats, indicating that the addition of 4 units of potassium was of no benefit. Likewise, the 10-6-8 plats containing the high potassium were no better than the 10-6-4 plats. The 10-12-4 (high phosphorus) plats were in all cases rated higher than the 10-0-4 (low phosphorus) plats, indicating that the addition of phosphorus was of benefit. With the exception of texture the ratings were higher on the 10-0-0 plats than on the 5-6-4 low nitrogen plats. It is quite apparent that nitrogen and phosphorus were more beneficial in influencing quality ratings than was potash.

The greatest invasion of clover occurred on the Rhode Island bent low nitrogen plats, the next highest on the high potash (10-6-8) plats, and the least on the high nitrogen plats. The high phosphorus plats had only a trace more than the low phosphorus plats. These results would indicate that low nitrogen and high potash favored the development of clover on the Rhode Island bent plats. In general, the Washington bent plats had at least 80 per cent less clover than the Rhode Island bent plats, the greatest amount occurring on the low nitrogen and the least on the high nitrogen plats. The addition of 12 units of phosphorus or 8 units of potash did not increase clover on the Washington plats. Piper velvet bent had the greatest resistance to clover. The greatest amount of clover was found on the 10-12-4 plats. This was more than twice as much as on the low nitrogen and low phosphorus plats, indicating that high phosphorus undoubtedly stimulated clover.

About twice as much time was taken weeding crabgrass on the low nitrogen and low phosphorus plats as on the high nitrogen plats of Rhode Island bent. The low and high potash plats had the most crabgrass on Washington bent and the least on the 10-0-0 and 20-6-4

plats. The high nitrogen plat of Piper and the 10-6-4 and 5-6-4 had the least crabgrass while the most was found on the low potash, low phosphorus and potash, and high phosphorus plats. The blocks of Washington had about one and one-half times as much crabgrass as did Rhode Island bent and the Piper blocks had the least.

The invasion of plantain on Rhode Island bent was greatest on the low potash plats. The least time spent in weeding was on the high nitrogen plats and, strange as it may seem, more time was spent weeding the other plats than was used on the low nitrogen plats. The highest weed populations found on Washington bent were on the 10-0-0, 10-6-4, and 10-6-0 areas and the lowest on the 10-0-4 and 10-12-4 plats. On Piper velvet more time was spent weeding the low nitrogen plats than the others, which were all very uniform in plantain content. Three times as much time was employed weeding the Rhode Island bent areas as on Washington bent and nine times as much as on Piper. Washington bent required three times as much time weeding as did Piper velvet. This should leave no doubts as to a comparison of the ability of these three species of *Agrostis* to compete against general lawn weeds, especially plantain.

The relation of large brownpatch and dollarspot diseases to the effect of different fertilizer ratios on Rhode Island Colonial, Washington creeping bent, and Piper velvet bent is given in Table II. Large brownpatch disease was more severe on Rhode Island bent than on the other species of grass. The greatest damage was done to the untreated plats and also the treated plats receiving the 10-0-4, 10-0-0, and 10-12-4 ratios. Considerable damage occurred on the 20-6-4 untreated plats but not so much as would be expected from the high nitrogen fertilizer. In fact there was slightly more damage done to the low nitrogen (5-6-4) plats than occurred on the 10-6-0, 10-6-8, and 10-6-4 plats. The high potash plat had the least disease of the untreated plats. Nine per cent of the total area of Rhode Island bent was infested on the untreated portions and less than 1 per cent on the treated areas.

On the Washington creeping bent untreated plats the 10-6-0 plats had more disease than the 20-6-4 plats; 10-6-4 plats were a close second to the 20-6-4 plats and 10-12-4 a close third. The smallest amounts occurred on the 5-6-4 and 10-0-0 plats. Again it is noted that the high nitrogen plats did not have the most disease.

With Piper velvet bent the 10-12-4 plats were more susceptible than the 20-6-4 high nitrogen plats and 10-0-4 plats were next in susceptibility. The least amount of brownpatch occurred on the 10-6-8 high potash plats which was also the case with Rhode Island bent. There was very little difference in susceptibility of the other plats. No brownpatch occurred on the treated plats of Piper velvet bent and the total average per cent of brownpatch on all untreated fertilizer plats was 1.51.

Less than .50 per cent of dollarspot appeared on any plat of Rhode Island bent. The most, .33 per cent, was on the low nitrogen (5-6-4) plat and the least on the high nitrogen (20-6-4) plat where only a trace was noted. The total average percentage of dollarspot on all plats was less than .1 per cent and only a trace on the treated areas.

TABLE II—RELATION OF LARGE BROWNPATCH AND DOLLARSPOT DISEASES TO DIFFERENT FERTILIZER RATIOS ON RHODE ISLAND COLONIAL BENT, WASHINGTON CREEPING BENT, AND PIPER VELVET BENT, 5-YEAR AVERAGE

Fertilizer Ratio	Per Cent Infestation			
	Brownpatch		Dollarspot	
	Treated	Untreated	Treated	Untreated
<i>Rhode Island Colonial Bent</i>				
10-0-0	1.21	11.40	Trace	0.07
10-0-4	1.44	12.94	Trace	0.10
10-12-4	1.04	9.57	Trace	0.03
5-6-4	0.73	8.39	Trace	0.33
10-6-0	0.44	6.63	Trace	0.05
10-6-8	0.72	6.53	Trace	0.07
10-6-4	0.85	6.93	Trace	0.09
20-6-4	0.63	10.17	Trace	Trace
Average	0.88	9.07	Trace	0.09
<i>Washington Creeping Bent</i>				
10-0-0	0.00	0.78	1.10	13.30
10-0-4	0.06	1.18	1.30	11.80
10-12-4	0.02	1.37	1.00	14.00
5-6-4	0.00	0.75	1.00	15.10
10-6-0	0.02	1.97	0.80	12.00
10-6-8	0.00	1.20	0.40	9.60
10-6-4	0.00	1.76	0.60	9.30
20-6-4	Trace	1.88	0.40	7.50
Average	0.01	1.36	0.83	11.57
<i>Piper Velvet Bent</i>				
10-0-0	0.00	1.23	0.00	0.00
10-0-4	0.00	2.00	0.00	0.00
10-12-4	0.00	2.27	0.00	0.00
5-6-4	0.00	1.59	0.00	0.00
10-6-0	0.00	1.01	0.00	0.00
10-6-8	0.00	0.36	0.00	0.00
10-6-4	0.00	1.58	0.00	0.00
20-6-4	0.00	2.04	0.00	0.00
Average	0.00	1.51	0.00	0.00

Washington creeping bent was quite severely attacked ranging from 15 per cent on the low nitrogen plats to 7.5 per cent on the high nitrogen plats where the least damage occurred. The 10-12-4 plats had 14 per cent; 10-0-0 plats had 13.3 per cent; 10-6-0 had 12 per cent; and 10-0-4 was 11.8 per cent affected. Similarly as with Rhode Island bent the greatest harm was done to the low nitrogen plats and the least to the high nitrogen plats. The total average percentage of dollarspot on all plats was 11.57 on the untreated and less than 1 per cent on the treated areas. Piper velvet bent was 100 per cent resistant to dollarspot on both the treated and untreated areas.

An average of soil samples taken in 1937 showed a pH of 5.5 which was the same as in 1933. This undoubtedly is because of a balancing effect of the chemical reaction and residues of the inorganic nitrogen carriers which were sulphate of ammonia and nitrate of soda.

#### SUMMARY AND CONCLUSIONS

A summary of results of a 5-year study of the effect of different fertilizer ratios on Colonial, creeping, and velvet bent grass indicates that

the most vigorous growth was obtained from fertilizers high in nitrogen and phosphorus. The addition of potash made no increase in vigor as measured by estimates of growth. Varying amounts of nitrogen influenced color ratings the most, the addition of phosphorus and potash had very little beneficial effect. Low nitrogen, in general, developed the finest textured turf which is just opposite from the highest ratings of color, density, and vigor which occurred from the use of high nitrogen. The most dense turf was a result of high nitrogen and the least dense from the low nitrogen; the high phosphorus plats of Piper and Rhode Island bent were superior to all but the high nitrogen plats. The addition of phosphorus or potash to the other plats made no great difference so it appears that nitrogen is mainly responsible for density and that phosphorus assists to some extent.

High phosphorus and low nitrogen favored the growth of clover. High nitrogen discouraged the invasion of clover, crabgrass, and plantain. Broad-leaved plantain was the most troublesome weed other than crabgrass in the first 2 years. Very few weeds of any kind appeared during the last 3 years, with the exception of small amounts of clover.

Large brownpatch disease was least severe on the high potash and low nitrogen plats. On Rhode Island and Washington bent, dollarspot was most severe on the low nitrogen, and least severe on the high nitrogen plats. Piper velvet was 100 per cent resistant to dollarspot.

Even though the high nitrogen fertilizer gave the highest quality ratings for vigor, color, and density, the turf grows too rapidly and is too spongy for practical putting green conditions; and while the low nitrogen plats had the highest rating of texture, they were more susceptible to invasion of clover and weeds, had a hard surface, and were more subject to drying out than were other plats.

The fertilizer applications made no apparent change in pH during this study. Taking all factors into consideration it appears that a complete fertilizer such as the 10-6-4 or 10-12-4, which have a comparatively high nitrogen content with part of the nitrogen in the inorganic form and part in the organic form together with sufficient phosphorus and potash to produce a good balancing effect, is more suitable for general applications as a topdressing fertilizer than incomplete or complete fertilizers of high or low nitrogen content when applied at the rate of about 35 pounds per season with the bulk of the fertilizer applied in early spring and fall.

Piper velvet bent was the outstanding grass and appeared more satisfactory than Rhode Island Colonial bent or Washington creeping bent in quality ratings based on density, texture, and color and weed and disease resistance.

## Growth Studies of King Alfred Narcissus Bulbs

By A. H. CURTIS, *U. S. Horticultural Station, Beltsville, Md.*

SINCE 1936 we have been conducting, in cooperation with the North Carolina State College of Agriculture and the North Carolina State Department of Agriculture, a series of fertilizer experiments on narcissus. One of these experiments has been concerned with time and method of application, and it was early recognized that more information was needed on the seasonal growth of the bulbs. With this in mind, the following experiment was begun in the fall of 1937 at the United States Horticultural Station, Beltsville, Maryland.

One thousand King Alfred narcissus bulbs were selected at random with certain limits of size and weight. The bulbs were grown at Bellingham, Washington, prior to 1936, when they were moved to and grown at Beltsville. Each bulb was weighed October 10 and planted October 11, 6 inches deep and 6 to 8 inches apart in rows 3 feet apart. Between lots of 50, a 2-foot space was left.

It was planned to dig the bulbs every month, but this was sometimes impossible due to unfavorable weather. When dug the soil was washed off and the entire plants weighed. The length of top on each bulb was recorded and is shown in Fig. 1. A complete fertilizer (5-8-5) was applied March 23, 1938, at the rate of 1,500 pounds to the acre, when the tops were 2 to 4 inches above the soil surface. The bulbs were in flower from April 3 to April 18, or about 15 days. The weather at that time was cool as compared with other years.

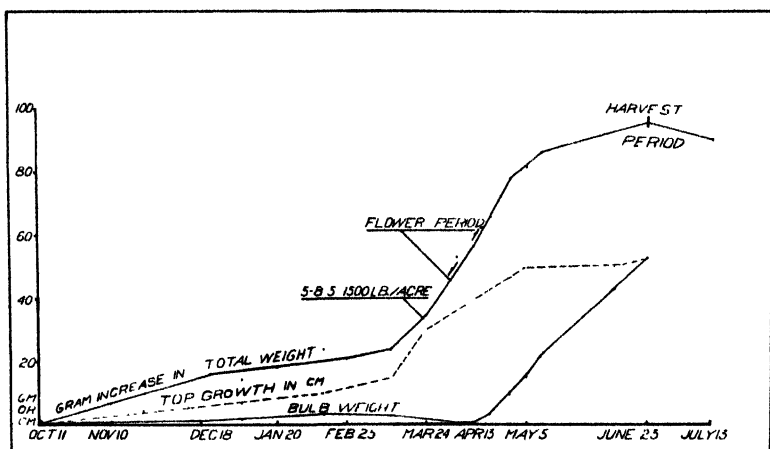


FIG. 1. Growth study of King Alfred Narcissus, 1937-38.

From Fig. 1 it can be quickly seen that the growth rate of the entire plant was rather slow from October 11 to March 1, at which time the tops were showing above ground and able to synthesize food, thus

speeding the growth rate considerably. It will be noted that at the time of flowering the bulb, with tops and roots removed, decreased almost to its original weight, but increased rapidly thereafter. The growth of the top parallels the increase in total weight but lags somewhat. The bulb increase parallels the top growth and total weight increase but also lags about 1 week.

This experiment is being repeated but adding another factor, namely, fall and spring application of fertilizer with a check having no fertilizer.



# Notes on the Storage of Wedgewood Iris Blooms

By T. M. WHITEMAN and R. C. WRIGHT, *U. S. Department of Agriculture, Washington, D. C.*

THE following tests on the storage of the cut blooms of Wedgewood Dutch iris were conducted at Arlington Farm near Washington, D. C. The blooms in tests I and II, were produced at Arlington Farm, whereas those in test III were grown near Reading, Pennsylvania.

The term "bud," or "in the bud," as used here, signifies a bloom that has not quite begun to open but shows considerable color; "full" or "full bloom" indicates one that has completed the opening process, having been open from a few hours to not more than 1 day. The word "good" is used to designate that condition or quality when on close inspection the bloom shows no abnormal curling, no desiccation or wilting, and no other tissue breakdown. This "good" appearance after storage does not infer that the blooms would be salable, because the lasting qualities usually have been impaired to some extent even though there was no evident curling or wilting. However, in the home the blooms are not ordinarily discarded for a day or so after the "good" condition, as designated here, is terminated.

## TEST I

These blooms were cut both in the bud and when fully opened. They were then stored in water for 1, 2, 3, 4, and 5 weeks at 32, 40, and 50 degrees F and a check lot was placed in water at 70 degrees. Upon removal from storage these blooms were held in water up to 5 days at a constant room temperature (70 degrees F).

## RESULTS

*Check Lot:*—Both the blooms cut in the bud and those cut at the full stage of maturity were of normal color and in good condition after 4 days in water at 70 degrees F.

*Condition After 1-Week's Storage:*—When removed from 32, 40, and 50 degrees F after 1 week's storage both the bud lots and those in full bloom when stored were in good condition, although the buds had opened at 40 and 50 degrees but were still tight in the 32 degrees lot. The blooms in the 32 degrees bud lot were good after 3 days at 70 degrees, but those in the 32 degrees full bloom lot were good only after 1 day at 70 degrees. The 40 degrees bud lot was good after 2 days at 70 degrees. The 32 and 40 degrees full bloom lots were good only after 1 day at 70 degrees. Those stored in the bud for 1 week at 50 degrees remained good for only 1 day at 70 degrees, the full bloom lot being slightly withered under the same treatment.

*Condition After 2-Weeks' Storage:*—The 32 degrees F bud lot after 2 weeks' storage was somewhat more developed than when stored but remained good for 2 days at 70 degrees, whereas the full bloom lot from 32 degrees lasted only 1 day at 70 degrees. The 40 and 50 degrees bud lots, the 40 degrees full bloom lot (but not the 50 degrees full

bloom lot) were good when removed from storage but not after 1 day at 70 degrees.

*Condition After 3-Weeks' Storage:*—When removed from 32 and 40 degrees F both the bud and full bloom lots were good after 3 weeks' storage. The 32 degrees bud lot remained in good condition at 70 degrees for 2 days, whereas neither the bud nor the full bloom lot from 40 degrees was good even after 1 day at 70 degrees. Those held at 50 degrees were not good upon removal after 3 weeks' storage.

*Condition After 4-Weeks' Storage:*—Both the bud and full bloom lots from 32 degrees F storage were good when removed, but only the bud lot was good after 1 and 2 days at 70 degrees. Of the two lots removed from 40 degrees only the bud lot was good and these remained so for only 1 day at 70 degrees.

*Condition After 5-Weeks' Storage:*—The bud and full bloom lots were both good when removed from 32 degrees F after 5-weeks' storage; only the bud lot, however, was good after holding 2 days at 70 degrees. The 32 degrees full bloom lot was evidently somewhat less mature when cut than any other similar ones since it remained good for 1 day at 70 degrees.

## TEST II

To simulate a shipping test Wedgewood iris blooms were cut in the bud stage and held in water overnight at 50 degrees F. The next day bunches of 10 to 12 blooms each were wrapped in waxed paper over wet newspaper butt wraps and were then packed in 175-pound test corrugated boxes. These boxed blooms were stored at 32 and 40 degrees and after 1, 2, and 3 weeks they were put into containers of water in a 70 degrees room where they were held up to 3 days. A check lot was placed in water at 70 degrees on the day that the boxed blooms were stored.

## RESULTS

*Check Lot:*—At 70 degrees F the check blooms were good after 3 days.

*Condition After 1-Week's Storage:*—Blooms from 32 and 40 degrees F storage were in good condition when unpacked and remained good for 1 day at 70 degrees.

*Condition After 2-Weeks' Storage:*—The blooms from 32 degrees F storage were good after 1 day at 70 degrees, but those from 40 degrees were not good when removed from storage.

*Condition After 3-Weeks' Storage:*—Blooms from 32 degrees F were not good when unpacked and did not improve when put in water at 70 degrees.

## TEST III

Wedgewood iris in full bloom in this test were cut in the morning, packed in 175-pound test corrugated boxes and transported by truck from Reading, Pennsylvania, to Arlington Farm, Virginia. Later the

same day they were placed in water at 50 degrees F where they remained overnight. On the following day several bunches of 10 to 12 blooms each were wrapped in waxed paper over a wet newspaper butt wrap and packed in a corrugated box which was stored at 32 degrees. These bunches were removed after 1, 2, 3, and 6 weeks and held in water at 70 degrees.

### RESULTS

These blooms when removed from the 32 degrees F storage after 1, 2, and 3 weeks were in good condition, but each lot held up satisfactorily for only 1 day at 70 degrees. Those removed from storage after 6 weeks were not good.

### DISCUSSION AND SUMMARY

It was found that freshly-cut buds of Wedgewood iris kept in good condition for 4 days when held in containers of water at 70 degrees F. The blooms cut at "full" maturity may not be expected to remain in good condition at 70 degrees for more than 3 days.

The buds used to simulate a shipping test (Test II) by wrapping and packing as for shipment were in water only overnight. This test showed that 1 week's dry storage at 32 and 40 degrees F so reduced the keeping quality that thereafter the blooms remained in good condition for only 1 day at 70 degrees. It was observed, however, that after 2 days at 70 degrees the blooms previously stored at 32 degrees appeared more attractive than those from 40 degrees storage.

The actual shipment (1 day by truck) involving blooms cut in the full stage of maturity (Test III) showed, that held at 32 degrees F for only 1 week or as long as 3 weeks, the blooms kept satisfactorily at 70 degrees for only 1 day. Held for 6 weeks at 32 degrees they were not in good condition when removed from storage.

Although these tests were merely incidental to other work and were not entirely complete they show the fallacy of attempting to hold buds of this variety of Dutch iris in water at a temperature much higher than 32 degrees F and for a period longer than 1 week. This recommendation, of course, is made with a view to subsequent holding at room temperature. The tests also suggest that at ordinary refrigerator temperatures customarily maintained by florists the same buds (especially after shipment) could probably not be held for longer than 2 or 3 days and still be salable as choice cut flowers.

# The Influence of Storage Temperatures on the Forcing of King Alfred Narcissus Bulbs

By D. VICTOR LUMSDEN, *U. S. Horticultural Station,  
Beltsville, Md.*

THE temperatures at which narcissus bulbs are stored during the summer are known to have a decided influence on the ultimate flowering response of the bulbs (1, 3, 4). The present investigation was conducted to determine how various storage temperatures influence early flowering and affect the number of flowers per bulb. Bulbs of *Narcissus pseudonarcissus* L., variety King Alfred, were used because of the widespread popularity of this variety.

The bulbs for this study were from a stock grown for a period of years at Bellingham, Washington, and shipped to the United States Horticultural Station, Beltsville, Maryland, during the summer of 1936. They were grown for 1 year under field conditions at Beltsville and dug June 24, 1937. From this date until July 19 the bulbs were cured in the bulb house with good air circulation. They were then graded and only double nosed or large round bulbs were used for the experiment. Thirty-five lots were assembled, 27 for controlled temperature treatments throughout the summer, and eight for checks. The lots were assembled by selecting 35 of the largest bulbs and using them separately to start each lot. The 35 next largest bulbs were then selected, and so on until each lot comprised 20 bulbs.

Each sample was put in a separate mesh bag. On July 23, 27 lots were divided into three groups of nine each; one group was stored at 90 degrees F, another at 80 degrees, and the third at 70 degrees. The remaining eight were left in common storage in the bulb house. The lots at controlled temperatures were kept thus for 2 weeks.

On August 6 they were removed. The nine from each early temperature were then divided into three groups of three, one being transferred to 50 degrees F, another to 40 degrees, and the third to 32 degrees. The bulbs were kept at these relatively low temperatures for 1 month.

On September 6 they were shifted from the mid-season temperature so that one lot from each previous temperature combination was placed at 80 degrees F, 70 degrees, and 60 degrees. In this manner each of the 27 lots received a different total treatment. Also on September 6, four of the eight lots remaining in the bulb house were placed at 50 degrees F. After 1 month all of the bulbs, including the four lots that had been in the bulb house all summer, the four that had received treatment for 1 month at 50 degrees F, and the single lots that received different combinations of three temperature treatments, were all planted in deep bulb flats, with each lot of 20 bulbs in a different flat. The flats were well watered and placed in the bulb house cellar on October 6.

On December 20 when shoots from the most advanced bulbs had reached a height of 2 inches, all the flats were moved to a greenhouse where the day and night temperatures were manually kept close to

55 and 50 degrees F respectively. The flats of bulbs remained here until flowering, all of which occurred between February 1 and 17.

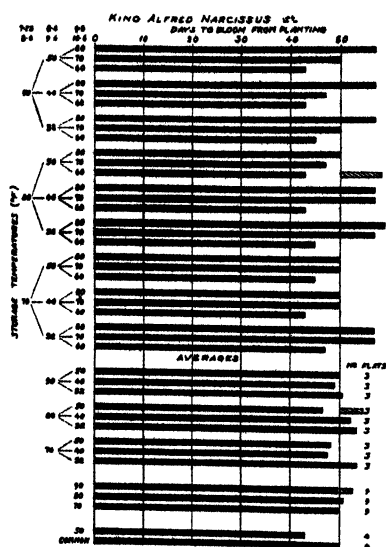


FIG. 1

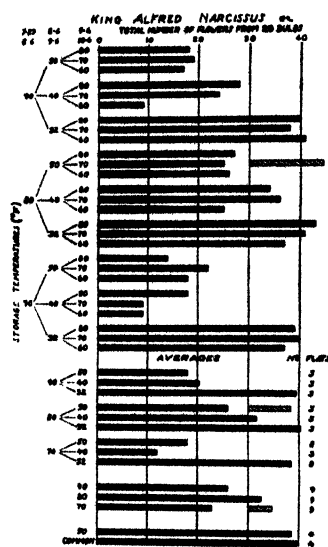


FIG. 2

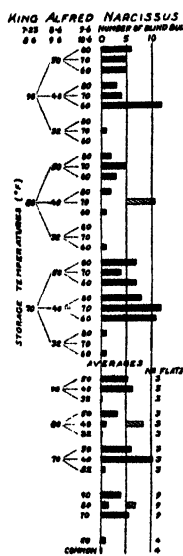


FIG. 3

FIG. 1. Comparative numbers of days to bloom of lots of King Alfred narcissus bulbs given various temperature treatments during summer storage.

FIG. 2. Comparative numbers of flowers of lots of King Alfred narcissus bulbs given various temperature treatments during summer storage.

FIG. 3. Comparative numbers of blind bulbs of lots of King Alfred narcissus bulbs given various temperature treatments during summer storage.

Figs. 1, 2, and 3 all indicate the temperature treatments each lot of bulbs received during summer storage. The lower part of each figure shows averages of the lots having the same early and mid-season temperature treatments, as well as those lots all having the same initial storage temperatures. Near the bottom of each figure are shown results from the check lots that were kept in common storage in the bulb house during the summer until September 6 and then placed in cold storage at 50 degrees F for 1 month. This treatment is currently popular for early forcing of narcissus bulbs and was advocated by Griffiths (3). The lowest bar on each figure is labeled "common" and shows

results for bulbs given no controlled temperature treatment, having been kept in the bulb house throughout the summer and planted in flats on October 6 at the same time as all other bulbs.

In each graph the three cross-hatched bars show how large differences must be in order to be considered significant by odds of 19:1. The values on which the length of these bars is based were derived from the standard errors of differences, which in turn are based on the variance of the entire experiment remaining after removal of the variance due to the three primary factors, or sets of temperature treatments. In other words, the sum of all treatment interactions plus error was used as a basis for determining the significance of differences between the primary effects of the treatments.

Fig. 1 shows the number of days required for each lot to come into full bloom. In all cases the bulbs that received 60 degrees F during the third and final storage period blossomed earlier than those receiving 70 or 80 degrees F during the same period. Likewise, bulbs that received 70 degrees F during the third period all bloomed as soon as, or sooner, than those which were stored at 80 degrees F. In the majority of cases there is a convincing significance between a final temperature treatment of 80 and 60 degrees F in favor of the latter for early flowering, while the 70 degrees F treatment shows a definite intermediate trend. The averages for the first and second period temperature treatments indicate some temperature combinations which give significantly shorter blooming intervals than do other temperatures, but for the averages of all bulbs combined under the initial temperatures of 90, 80, and 70 degrees F there is no apparent significance between these temperature treatments. From Fig. 1 we can conclude that bulbs from the three final storage temperature treatments show a definite trend for earliness in favor of the 60 degrees F treated bulbs. The 70 degrees F treatment shows intermediate results, while that at 80 degrees F is significantly higher than the 60 degrees F treatment.

Fig. 2 shows the number of flowers resulting from bulbs given the storage temperature treatments as described above. In this consideration the treatments giving the greatest number of flowers are of importance. The upper two-thirds of the figure showing results of individual treatments reveals only one case where one lot is significantly different from another that received the same early and mid-season storage temperatures. This is between bulbs having the 90-40-80 degrees F and the 90-40-60 degrees F treatment. The difference here is 19, with only 15 required to give 19:1 odds. The long bars for bulbs having a mid-season treatment of 32 degrees F stand out in the upper part of the figure for individual treatments but are even more pronounced under the averages of late season treatments. Here all 32 degrees F treatments show significant increases whether the initial temperature be 90, 80, or 70 degrees F, while in no case is there significance between the 50 and 40 degrees F mid-season temperatures. The averages of nine lots receiving original temperatures of 90, 80, and 70 degrees F show that 80 degrees F gives significantly more flowers than did either 90 or 70 degrees F, with no significance be-

tween the two latter. The conclusions from Fig. 2 are these: Of the temperatures employed in this investigation a low of 32 degrees during mid-season storage resulted in the maximum number of flowers; in addition, an early temperature of 80 degrees gives significantly more flowers than either 90 or 70 degrees F.

Non-flowering or "blind" bulbs occasionally occur in forcing; an analysis of the blind bulbs resulting from the temperature treatments heretofore described is shown in Fig. 3. The results of individual treatments show in only one case a significantly large difference over other lots with the same mid-season temperature, the 90-40-60 degrees F with 12 blind bulbs, and its 80 and 70 degrees associates differing by 8 and 7 blind bulbs with only 6 needed for significance. The averages of lots having the same early and mid-season treatments show that in all cases a mid-season temperature of 32 degrees F for the experiment resulted in few blind bulbs, while 50 and 40 degrees F caused significant increases in blind bulbs in the lots having an initial temperature of 90 and 70 degrees F, but not 80 degrees F. This is more clearly shown in the averages of all nine flats which received the original 90, 80, or 70 degrees F, where the number of blind bulbs at 80 degrees is significantly lower than those at 90 or 70 degrees F.

A comparison with the results secured from the check lots, which are shown at the bottom of each figure, indicate that the earlier recommendations of giving narcissus bulbs warm storage to within 1 month of planting, followed by a storage period of 1 month at 50 degrees F just prior to potting or flatting them up, are still most desirable to get accelerated flowering and a relatively high flower yield. The lots which remained in common storage throughout the summer and had no controlled temperature treatment are shown to have given a good yield of flowers but to have been slow in coming into bloom.

### CONCLUSIONS

In the light of results revealed by this investigation it is planned to carry on further work to gain more information concerning the detailed response of narcissus bulbs to different temperatures during summer storage. This work has shown that a surprisingly low storage temperature of 32 degrees F during mid-summer resulted in giving a high yield of flowers, and that a late storage period of 60 degrees was more effective in accelerating flowering than either 70 or 80 degrees F. Furthermore, interactions of the different storage temperatures during the summer in some cases influenced the action of the temperature which was shown to have been most effective in producing accelerated flowering, a greater number of blossoms, or blind bulbs.

A word of caution should be given concerning the application of the findings of this work to the forcing of other narcissus. Griffiths' work (2, 3) indicated that varieties vary widely in their forcing responses. Van Slogteren has shown (6) that early lifting of bulbs may result in irregular or retarded flowering or dwarf flowers so that bulbs must be well matured in the field before they are dug. The time advisable for digging bulbs will vary with both the location and the year. It must also be borne in mind that the new flowers are already partially formed

in narcissus bulbs (5) before they are dug in the spring, and the time of digging can greatly influence the further development of the flower. The time of the year the forcing takes place will also modify the treatment the bulbs must receive for successful forcing. Finally, the temperature of the greenhouse in which the bulbs are ultimately grown and forced into flower demands consideration. Any recommendations, based on experiments, for the treatment to be given bulbs for satisfactory forcing must be considered in the light of the previous history of the bulbs used in the experiment from which the recommendations resulted.

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## Fertilizer for Narcissus Bulbs in North Carolina (Progress Report)

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THE production of hardy daffodil bulbs in the United States is concentrated chiefly in the Pacific Northwest, Long Island, and the Castle Hayne area in North Carolina. On Long Island, North Carolina, tidewater Virginia, and the Eastern Shore of Maryland, cut flowers for market also form an important part of the industry.

One of the problems confronting the growers is the choice and efficient use of fertilizers. Very little is known about the kind and amounts needed or about the best time and method of application for flower or bulb production. To solve some of these problems a fertilizer experiment was started at Castle Hayne, North Carolina, in 1936, which has now been under way for 2 years. This experiment is concerned with type and rate of fertilizer application. In 1937 a second experiment was started to study placement and time of application of fertilizer. Only 1 year's results are available on the latter experiment.

The data reported in this paper are to be considered purely as a progress report. Further experiments now under way, which later may justify some conclusions, will be reported on as the work progresses.

### MATERIALS AND METHODS

Since King Alfred is the most widely grown variety of daffodil, it has been used throughout these experiments. The first year the bulbs were all large slabs, graded for uniformity. The second year they were the same ones, but were now large rounds, following the 1 year's growth. The second experiment on time and method of application (started in 1937) was also begun with uniform large slabs. Each year the planting weight, per plot, has been standardized at a uniform figure.

The bulbs have been planted each year in another field, on which the pH was determined from a series of tests scattered over the plot. When the tests consistently ran lower than pH 6, lime was added to bring it up to or near that level.

The first experiment started in 1936 consisted of 20 different treatments at two rates of application, 1,000 and 2,000 pounds per acre. Each treatment was replicated four times, making five plots of each or a total of 200 plots which were arranged in a modified Latin square planting. Each plot consisted of four rows, each  $16\frac{3}{4}$  feet long, holding 50 bulbs. The rows were  $2\frac{1}{2}$  feet apart, and the records were taken from the two middle rows.

The second year the same bulbs were used again, since it was thought there may be a carry-over effect in the bulbs from the previous year's fertilizer. Thus those bulbs receiving treatment no. 1 in 1936-37 received the same one again in 1937-38. Since some bulbs are lost each year, chiefly because of rots, and it also becomes more difficult to get

lots of 100 that are uniform in weight, the second year's experiment included only three plots of each treatment instead of five. Size of plot and planting distances were the same.

The experiment on time and method of fertilizer application included 17 variables. The plots were 30 feet in length and consisted of seven rows of 100 bulbs each. Records were taken from the five middle rows. Each plot was replicated twice, making three of each treatment and a total of 51 plots arranged in a modified Latin square.

In the first experiment the same source for each element was used each year. For nitrogen it was dried blood and tankage, for phosphorus it was superphosphate, and with one exception the potassium source was muriate of potash. The minor elements with their source and rate per acre were as follows: (a) Copper-Cu-copper sulphate, 10 pounds per acre; (b) Boron-B-borax, 3 pounds per acre; (c) Manganese-Mn-manganese sulphate, 5 pounds per acre; and (d) Magnesium-Mg-magnesium sulphate, 60 pounds per acre.

All these elements were mixed and applied with the fertilizer, which in the first experiment was placed in the bottom of the furrow and mixed into the soil with a small garden tractor. The method of application varied in the second experiment and is shown in Table II.

For the second experiment, on time and method of application, the same sources of nitrogen, phosphorus and potassium, with certain exceptions were used as in the first. In the plots where calcium nitrate was used for a side dressing, and when a soluble 3-8-0 or 3-8-10 fertilizer was used, the nitrogen came from calcium nitrate and the phosphate from soluble triple superphosphate. The same amount of available nitrogen, phosphorus, and potassium was used in each plot regardless of the source, except in plot 4, where the rate per acre was changed from 1,000 to 2,000 pounds.

## RESULTS

In each experiment data were recorded on yield of bulbs and number of rotted bulbs, and the second year on number of flowers also. The first year's results showed no difference in yield of bulbs between any two of the 20 treatments, nor between the rates of 1,000 and 2,000 pounds per acre. The small differences which did occur were all traceable to soil heterogeneity.

The number of bulbs rotting in storage showed a small but significant increase in the lots receiving 2,000 pounds of fertilizer. The increase was so small that it could not be traced to any one element or combination of elements. There was no significant difference in rots between treatments or as a result of soil heterogeneity.

In the second year there were again no significant differences in yield of bulbs between any of the treatments, rates, or from any other cause. The soil was evidently more uniform.

The data regarding rots the second year again showed an increase in the 2,000 over 1,000 rate of fertilizer application, but it was impossible to trace this to any one element or combination. There was, however, a significant increase in rots traceable to soil. This will be discussed later in the paper.

Flower yield records were not taken the first year. The second year, however, the number of flowers cut per plot were recorded and the results are given in Table I. This also shows the 20 treatments and since the difference in flower yields was due to treatments and not to rates of application, the mean yield in each case is from six plots, comprising both 1,000 and 2,000 rate of application. It will be noted that a difference of 8.74 flowers is required for significance if odds of 19 to 1 are taken as the limits of experimental error. The treatments are listed in the order of flower yield and the first six all contain the same 3-8-10 fertilizer plus the minor elements. It will be noticed, however, that boron is the only minor element common to all six. A glance at the lower part of the table also shows that copper, manganese, and magnesium in combination with the same 3-8-10, all gave uniformly low flower yields. The mean yield of all the boron plots is 149.69 flowers and for all others 134. All the treatments lacking boron, except 7 and 8 gave significantly fewer flowers than the 6 plots on which it was used. Treatments 9 and 12, consisting of 3-8-10, do not differ from one another, but are less than all the boron plots. In all instances these yields are from approximately the same number of plants.

TABLE I—EFFECT OF FERTILIZER TREATMENT ON FLOWER YIELDS (1937-38)

Fertilizer	Mean Number of Flowers Per Treatment
1. 3-8-10+B.	153.67
2. 3-8-10+Mn, B, Mg	152.83
3. 3-8-10+Cu, B, Mg	152.16
4. 3-8-10+B, Mg	148.16
5. 3-8-10+Cu, B	147.50
6. 3-8-10+Mn, B	143.83
7. 3-4-10	139.83
8. 3-8-5	139.33
9. 3-8-10	134.00
10. 6-8-5	130.50
11. 3-4-5	130.00
12. 3-8-10 (K from K <sub>2</sub> SO <sub>4</sub> )	128.50
13. 6-4-5	128.33
14. 3-8-10+lime	128.17
15. 3-8-10+Cu	126.16
16. 6-8-10	125.33
17. 3-8-10+Mn	125.33
18. 3-8-10+Cu, Mg	125.00
19. 3-8-10+Mn, Mg	120.50
20. 6-4-10	120.17

2 × S. E. of a difference between means of 6 = 8.74 flowers

The second experiment, which was concerned with time and method of application of fertilizer, gave no significant difference in yields of bulbs between any of the 17 treatments. There was also no difference in flower yields. The soil was very uniform, and variance due to blocks was not significant for yield or number of flowers.

The data regarding number of bulbs rotting in storage, however, showed a significant difference between blocks 2 and 3. The various treatments and data on rots are shown in Table II.

### SUMMARY

Since this paper is merely a progress report, no general conclusions, discussions of literature, or recommendations are in order. It must also

TABLE II—OCCURRENCE OF ROTTEN BULBS IN RESPONSE TO TIME AND METHOD OF APPLICATION OF FERTILIZER (1937-38)

Treatment	Blocks		
	1	2	3
1. Furrow (fall) 3-8-10 1000 pounds . . . . .	22	29	39
2. Broadcast and disked (fall) 3-8-10 1000 pounds . . . . .	27	37	45
3. Drill beside row after planting (fall) 3-8-10 1000 pounds . . . . .	26	30	32
4. Furrow (fall) 3-8-10 2000 pounds . . . . .	4	18	37
5. Furrow (fall 3-8-10 1000 pounds +spring side dressing) . . . . .	35	67	34
(200 pounds $\text{CaNO}_3$ as tops appear)			
6. Furrow (fall 3-8-10 1000 pounds +spring side dressing) . . . . .	65	53	91
(200 pounds $\text{CaNO}_3$ after flowering)			
7. Furrow (fall 3-8-10 1000 pounds +spring side dressing) . . . . .	53	51	43
(1000 pounds 3-8-0 soluble as tops appear)			
8. Furrow (fall 3-8-10 1000 pounds +spring side dressing) . . . . .	40	47	22
(1000 pounds 3-8-0 soluble after flowering)			
9. Furrow (fall 3-8-10 1000 pounds +soluble 3-8-10) . . . . .	18	34	54
(1000 pounds as tops appear)			
10. Furrow (fall 3-8-10 1000 pounds +soluble 3-8-10) . . . . .	21	31	28
(1000 pounds after flowering)			
11. Spring side dressing only . . . . .	33	14	87
(1000 pounds regular 3-8-10 as tops appear)			
12. Spring side dressing only . . . . .	31	43	93
(1000 pounds soluble 3-8-10 as tops appear)			
13. Spring side dressing only . . . . .	33	18	58
(1000 pounds regular 3-8-10 after flowering)			
14. Spring side dressing only . . . . .	40	32	58
(1000 pounds soluble 3-8-10 after flowering)			
15. Spring drill 4 inches each side of row . . . . .	34	35	54
(1000 pounds regular 3-8-10 as tops appear)			
16. Spring drill 4 inches each side of row . . . . .	20	48	26
(1000 pounds regular 3-8-10 after flowering)			
17. Check (no fertilizer) . . . . .	48	31	67
Totals . . . . .	550	618	868
Means . . . . .	32.35	36.35	51.06

2 X S. E. of a difference between means of 17 = 10.68

be remembered that fertilizer experiments in general can not be relied on to give the same results in other localities or even on adjoining farms. There are too many factors operating. The data reported in this paper have been secured from two distinctly different fields for the 2 years.

The immediately preceding history of the two fields is presented here as it might have some bearing on the results. The field used in 1936-37 had not been farmed for some time because it was considered too poor. There is no record of any fertilizer ever having been applied. Preceding the planting of the bulbs, a crop of soybeans was planted, but it was a failure because of weeds.

The field used in 1937-38 was level and appeared uniform. In the early spring of 1937 a crop of lettuce was grown which received a heavy application of a 7-5-7 fertilizer and side dressings of sodium nitrate. The lettuce was followed by corn to which no fertilizer was applied.

In each year and in both experiments there were no significant differences in yield of bulbs between any of the fertilizer treatments used.

The results on flower yields indicate a stimulation by boron of new growth centers in the daffodil bulbs. Since the current season's flowers are laid down during the preceding year and are well developed at planting time, the effect of the boron is delayed 1 year. While no data were secured as to relative numbers of mother bulbs produced in the

various treatments, the flower yields indicate that many more occurred in the lots receiving boron. Since boron also has a very definite toxic effect on many plants, even when present in small quantities, it is felt that this phase of the work needs considerably more investigation before applications of boron are used in commercial narcissus culture. It must also be remembered that the amount of boron in the soil may vary considerably in different regions.

The data on bulbs rotting in storage are difficult to interpret. While in both years there was a significant increase between the rates of 2,000 and 1,000 pounds, it was not possible to trace it to any one element or combination, and the difference only slightly exceeded the 5 per cent point. The difference in rot due to blocks, as mentioned earlier in the paper, was rather large in the second experiment run in 1937-38.

Since the bulb samples for planting were taken at random from a large stock, and were again randomized in planting, it is improbable that the difference in rot in the crop from different blocks was due to different amounts of latent rot in the original samples. The rather large differences noted may possibly be due to soil factors of unknown nature or to differences in storage conditions. The storage record does not show whether all the bulbs from one block were stored together and possibly exposed to some adverse factor or factors that did not affect the bulbs from other blocks.

## Effect of Several Growth Substances on Various Storage Organs

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### ABSTRACT

This paper will be published in full in the *Contributions from Boyce Thompson Institute*.

SINCE vegetative storage organs are modified stems or roots it is to be expected that they should respond to treatment with growth substances, as shown in a variety of ways for normal green tissue. Tubers, corms, bulbs, and storage roots were treated in various ways with several of the most effective substances, naphthaleneacetic acid, indolebutyric acid, indoleacetic acid, cinnamic acid, and phenylacetic acid, and were found to respond in several ways. The following summaries show some of the more interesting results.

**Onions:**—Three varieties of onions (white, Yellow Globe, and Italian Red), treated by immersing the bulbs in a water solution of naphthaleneacetic acid (50 milligrams per liter) and indolebutyric acid (100 milligrams per liter) for 24 hours before planting in sand, formed many more roots than the water controls. Roots were induced to form all over the crown in contrast to the controls which rooted largely from the basal part. Some of the roots arising from the upper part of the crown were trapped between the scales and grew out of the top of the bulb. There was very little difference between the shoot growth of controls and treated bulbs with the low concentrations but higher concentrations retarded growth of shoots.

Roots of onions induced with naphthaleneacetic acid were more succulent and had a larger diameter than normal roots and larger than those induced with the indole compounds. Garlic responded to the substances very much like onions.

**Narcissus (variety King Alfred):**—The response of narcissus bulbs was similar to that described for onions.

**Carrots:**—Carrots immersed for 24 hours in solutions as described for onions showed profuse root growth (Fig. 1, E). Indoleacetic acid was much less effective than indolebutyric and naphthaleneacetic acids when comparable concentrations were used.

**Parsnips:**—The response was similar to that of carrots though the new roots came more in rows and had a tendency to split open the fleshy part of the root. The roots induced with naphthaleneacetic acid were of larger diameter than normal.

**Beets:**—There was no marked effect of the substances with the concentrations (50 to 100 milligrams per liter) used.

**Gladiolus:**—Several varieties of dormant and non-dormant gladiolus corms were treated with water solutions of the growth substances. The period of treatment was usually 24 to 48 hours, excepting when the corms were immersed while being subjected to vacuum in which case the length of treatment was 20 minutes to 1 hour. In addition to being

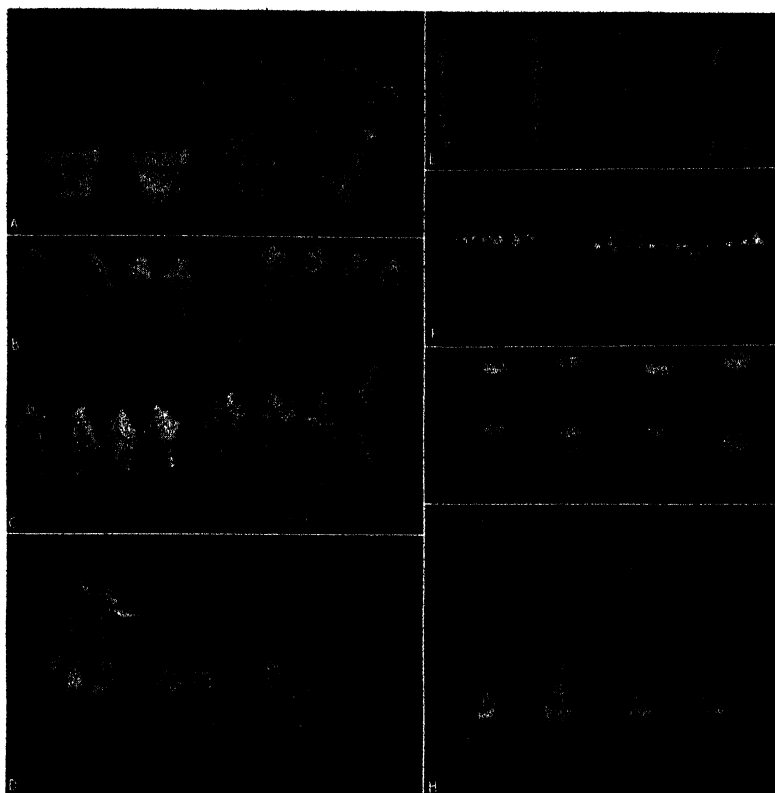


FIG. 1. Responses of storage organs to growth substances. A, *Helianthus tuberosus*. Dormant tubers treated on December 12, 1935 and results photographed January 23, 1936. Left to right: 1, and 2, water controls; 3, treated 4 days with solution of phenylacetic acid (500 milligrams per liter); 4, same as 3, except cinnamic acid was used. B, *Helianthus* tubers as they came from the field November 25, 1936. C, Same tubers as in "B" rephotographed December 18. Right, treated 4 days with naphthaleneacetic acid (50 milligrams per liter). D, *Helianthus* non-dormant tubers treated with naphthaleneacetic acid (50 milligrams per liter) for 24 hours. Left to right: 1, water control; 2, solution not aerated; 3, solution aerated with carbon dioxide; 4, solution aerated with oxygen. E, Carrots treated 24 hours and photographed 10 days later. Left to right: 1, water control; 2, indoleacetic acid (100 milligrams per liter); 3, indolebutyric acid (100 milligrams per liter); 4, naphthaleneacetic acid (50 milligrams per liter). F, Results of treating scales of *Lilium craba* with indolebutyric acid (2.5 milligrams per liter) April 21, photographed July 18. G, *Gladiolus* corms treated for 1 hour in partial vacuum when dormant and photographed 24 days later. Left to right: 1, water control; 2, naphthaleneacetic acid (50 milligrams per liter); 3, indoleacetic acid (100 milligrams per liter); 4, indolebutyric acid (100 milligrams per liter). H, Non-dormant *gladiolus* corms treated 24 hours in solutions. Left to right: same as "G". Note difference in roots induced with naphthaleneacetic acid.

immersed the corms were aerated with oxygen and carbon dioxide while in the water solutions.

The response of corms varied with the concentrations and the substances used. Naphthaleneacetic acid had a tendency to induce fleshy roots at the base of the corm resembling contractile roots normally formed at the base of new corms about flowering time. The dormant corms varied in their capacity to root after the chemical treatment. Fig. 1, G shows a characteristic type of rooting of varieties that responded. Indolebutyric acid (100 milligrams per liter) and naphthaleneacetic acid (50 milligrams per liter) were more effective than indoleacetic acid. Roots induced with the indole compounds resembled normal roots (Fig. 1, H). Both indolebutyric acid and naphthaleneacetic acid were effective for inducing contractile roots within a few days after treatment whereas normally contractile roots arise at the base of newly developing corms as flower primordia are forming. The growth substances induced these roots from the upper end of old corms even in the absence of a shoot. The contractile roots induced by naphthaleneacetic acid had a tendency to be fasciated and fleshy, forming a complete ring around the new shoot. The higher concentrations of indolebutyric acid induced a few fasciated contractile roots but generally they resembled the normal type. Under certain conditions corms were induced to form roots all over the storage organ though normally they form only around the basal part of the axis. Corms aerated with oxygen withstood treatment much better than those aerated with carbon dioxide. The latter had a tendency to disintegrate but if the treatment was stopped in time it was the most effective for inducing adventitious roots throughout the storage tissue. A substance giving the indole test (Winkler and Petersen) was detected in growing roots and shoots 24 days after indolebutyric acid had been applied to the corms.

*Lily (Erabu)*.—Scales of the lily bulb were treated with water and indolebutyric acid (2.5 milligrams per liter) for 24 hours and then covered with moist sand in a greenhouse bench. The scales treated with the growth substance remained in better condition than the water controls and produced many more bulblets as shown by Fig. 1, F. The scales were treated on April 21, and the results were photographed July 18. Leafy stem cuttings of this and other lilies were also treated with indolebutyric acid in an effort to induce roots. No roots were induced but axillary bulblets were formed on treated stems much more than on water controls. Leaves of *Lilium candidum* formed adventitious roots but no bulblets when treated with indolebutyric acid.

*Helianthus tuberosus*.—Both dormant and non-dormant tubers of *Helianthus* were treated for 24 to 96 hours with naphthaleneacetic, indoleacetic, indolebutyric, phenylacetic, and cinnamic acids. The responses varied with the condition of the tubers, the substances, and the concentration of the substances. Fig. 1, A. to D illustrates several responses. Naphthaleneacetic acid (10 milligrams to 50 milligrams per liter) was the most effective root-inducing substance (Fig. 1, C) and the phenyl compounds (250 to 500 milligrams per liter) were the most effective to break the dormancy of the buds (Fig. 1, A). Indolebutyric



and indoleacetic acids (100 milligrams per liter) increased rooting and in some cases caused sprouting of the dormant tubers but the results were variable and could not be repeated with certainty. In general the substances most effective for inducing abundant root growth inhibited shoot growth of both dormant and non-dormant tubers. This holds, also, for normal stem tissues as shown from treatment of intact plants and cuttings of dormant or growing plants. The phenyl compounds (phenylacetic and phenylacrylic acids) are comparatively ineffective for inducing roots, but induced shoots to grow from dormant tubers. This indicates a qualitative difference between accepted growth substances in their capacity to induce responses other than cell elongation. Since growth substances in general are known to retard bud growth and induce roots, the phenyl compounds constitute exceptions to this rule.

Several sets of tubers were aerated with oxygen and carbon dioxide during treatment in order to determine the effect of these gases on the activity of the compounds. The results indicated slightly increased root growth where the tubers were aerated with carbon dioxide and in the case of the phenyl compounds shoot growth was slightly increased when dormant tubers were treated. Oxygen gas injured the tubers if the aeration of the solution in which the tubers were immersed was continued for more than 24 to 36 hours. Carbon dioxide gas was bubbled through the solution for 96 hours without killing the tubers. Oxygen aeration for 48 hours caused the basal parts of tubers to become mushy, though in some cases the buds remained alive (Fig. 1, D). The effect of these gases on *Helianthus* tubers is to be contrasted with that of *gladiolus* corms which tolerated oxygen better than carbon dioxide.

The normal rest period of the white variety of *Helianthus* tubers used in these experiments extends through December if the tubers are left in the ground or stored outside. If planted in a warm greenhouse during the rest period, tubers show some activity but do not produce normal shoots. Under greenhouse conditions, buds of dormant tubers frequently produce new tubers. This type of growth may continue for months in a warm house without producing shoots. Phenyl compounds sometimes partially broke the dormancy, some buds producing shoots and others new tubers. Except for the very lowest concentrations, naphthaleneacetic acid prevented shoots and new tubers from forming. There was very little effect where non-dormant tubers were treated with the phenyl compounds, but the naphthalene compounds retarded or completely inhibited bud growth of both dormant and non-dormant tubers. Potassium naphthaleneacetate and other salts of naphthaleneacetic acid were equally as effective as the acid. This was true also for the other growth substances mentioned above.

## Effect of Synthetic Growth Substances on Various Types of Cuttings of *Arctostaphylos Uva-Ursi*<sup>1</sup>

By J. A. DeFRANCE, *Rhode Island Agricultural Experiment Station,  
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**A**RCTOSTAPHYLOS UVA-URSI (Bearberry) is a broad-leaved evergreen belonging to the *Ericaceae* or Heath family. This prostrate, creeping ground cover is in considerable demand for planting in sandy soils along roadside embankments, railroad cuts, and on home grounds for slopes and terraces of a sandy soil nature for erosion control. On the Coastal Plain, it seems to prefer sandy acid soil where lime has leached away from the sand. Roberts and Rehmann (5) classify it in their seaside association of plants and it is quite desirable as a ground cover to be used instead of grass on sandy soils near the seashore. It is difficult to say how many thousands of plants are lost annually in attempts to transplant bearberry from locations where it is growing naturally to places where it is desired, such as those mentioned above. With the thought in mind that *Arctostaphylos* was hard to transplant, and knowing that pot-grown plants and young field-grown plants could be depended upon to give far better results than native collected material, it was considered timely to try certain experiments regarding the rooting of bearberry cuttings, and to try to ascertain what type of cutting would be most suitable to use for propagating purposes when treated with synthetic growth substances.

Thimann (7) discusses the effect of indoleacetic acid on the rooting of Concord grape cuttings and states that "in the normal plant, root formation is achieved by the migration, to the base, of auxin produced in the growing buds and in the leaves."

The experiments with lemon cuttings by Cooper (1) give the following summary: "(a) when applied at the base of cuttings for 15 hours, only a strong solution of hetero-auxin is effective in inducing root formation; (b) cutting off the treated portion of the base nearly eliminates the effect of the treatment; (c) re-treating after cutting off the treated base causes no more roots than when not re-treated. To explain these facts, it is suggested that a strong solution of hetero-auxin, when applied to the base, causes the rapid movement downward of a substance, rhizocaline, present in the leaves and stem, which is necessary for root formation. Cutting off  $\frac{3}{4}$  inch of the base after treatment, cuts off most of the supply of rhizocaline and further treatment with hetero-auxin has little effect since hetero-auxin is only one of the substances necessary for root formation."

Hitchcock and Zimmerman (3) reported earlier rooting of cuttings of *Ilex* and *Taxus* when treated with growth substances such as indoleacetic acid. DeFrance (2) reported the rooting of *Daphne cneorum* 80 per cent and *Taxus cuspidata* 100 per cent in six weeks time by the aid of certain growth substances. Skinner (6) treated cuttings of several ericaceous plants with indolebutyric acid and indoleacetic acid

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but apparently did not include *Arctostaphylos* in his study. Poesch (4) gives a list of certain ornamental plants and their response to treatments of indolebutyric, indoleacetic, and naphthaleneacetic acids and also gives a list of "plants that did not respond to treatments with growth substances". Included in this list is *Arctostaphylos uva-ursi*.

#### MATERIAL AND METHODS

Indolebutyric acid crystals were used to make a concentrated stock solution by dissolving 1 gram indolebutyric acid crystals in 95 cubic centimeters of 95 per cent ethyl alcohol, then after the crystals had dissolved, 155 cubic centimeters of distilled water was added, making 250 cubic centimeters concentrate in 38 per cent ethyl alcohol approximately. From this stock solution further dilutions were made such as R. I. No. 3 by adding 1 quart of water to 5 cubic centimeters, and R. I. No. 4 by adding 1 quart of water to 10 cubic centimeters of the stock solution. These dilutions of the stock solution are approximately 5 cubic centimeters per 1000 cubic centimeters water or 2 milligrams indolebutyric acid per 100 cubic centimeters water and 10 cubic centimeters per 1000 cubic centimeters or 4 milligrams per 100 cubic centimeters water. Commercial root-inducing preparation was also used. A No. 3 solution was prepared by adding 1 quart of water to 5 cubic centimeters commercial preparation, and A No. 4 solution by adding 1 quart water to 10 cubic centimeters of commercial preparation.

Cuttings were made February 3. Four types of cuttings were used in the experiment: namely, (a) multiple terminal, which had three or more shoots on a single branch; (b) single terminal; (c) single terminal from which about 1 inch of the tip had been removed; and (d) heel cuttings which were lateral shoots pulled from a main stem.

The bases of the treated cuttings were immersed to a depth of 1 inch in the solutions for 24 and 43 hours, respectively. The bases of the control or check cuttings were immersed in water for the same period of time. At the end of treatment they were placed in a rooting medium which consisted of one-third peat moss and two-thirds sand. Bottom heat was

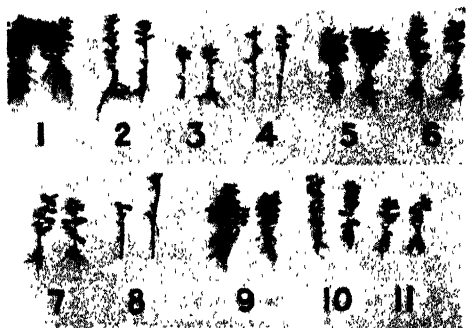


FIG. 1. Effect of synthetic growth substances on various types of cuttings of *Arctostaphylos uva-ursi*. 1, 2, 3, 4, multiple terminals, single terminals, heels, and single terminals with 1 inch of tip removed, treated in A No. 4 solution 24 hours; 5, 6, 7, 8, multiple terminals, single terminals, heels, and cut terminals treated in R. I. No. 3 for 24 hours (2 milligrams per 100 cubic centimeters water); 9, 10, 11, multiple terminals, cut terminals, and heels in A No. 4 for 43 hours.

applied electrically and the temperature of the bench was maintained

at approximately 76 degrees F. No covering other than cheesecloth, 4 inches above the cuttings, was used for shade or protection from evaporation or transpiration.

### RESULTS AND DISCUSSION

The bases of some of the cuttings were examined on March 3, 1 month after treatment, and it was noted that the first cuttings to develop roots were the multiple terminals.



FIG. 2. Effect of synthetic growth substances on various types of cuttings of *Arctostaphylos uva-ursi*. 1, 2, 3, multiple terminals, single terminals, and cut terminals in R. I. No. 3 for 43 hours; 4, 5, 6, 7, multiple terminals, single terminals, cut terminals, and heels in A No. 3 for 43 hours; 8 and 9, multiple terminals and single terminals in A No. 3 for 24 hours; 10 and 11, multiple terminals and single terminals in R. I. No. 4 (4 milligrams per 100 cubic centimeters water) for 24 hours.

This action appears to indicate that the multiple terminal cuttings contained more natural auxin than the other types of cuttings that had fewer tips and leaves. All the cuttings were removed from the bench on April 18. The results are shown in Tables I and II and Figs. 1 and 2.

Cuttings treated with A No. 3 solution for 24 hours gave the following results: 87 per cent of the multiple terminals rooted; 73 per cent of the single terminals rooted; no terminals with tips removed rooted; and 53 per cent of the heels rooted. When treated with R. I. No. 3 solution for 24 hours the following results occurred: 87 per cent multiple terminals;

80 per cent single terminals; 27 per cent terminals with tips removed; and 80 per cent of the heel cuttings rooted.

Comparing the results of the two solutions (R. I. No. 3 and A No. 3 for 24 hours) it is noted that very little difference occurred between multiple or single terminals; none of the terminals with cut tips rooted in A No. 3 and only 27 per cent in R. I. No. 3; heel cuttings treated with A No. 3 were considerably lower than with R. I. No. 3. Concerning the different type cuttings it is seen that in both cases the multiple terminals produced the greatest percentage of rooted plants; the percentage of rooted single terminals was somewhat higher than the heels, and the terminals with tips removed were very low in percentage of rooting.

When treated for 43 hours in A No. 3, 80 per cent of the multiple terminals rooted; 60 per cent of the single terminals rooted; 33 per cent of the single terminals with cut ends rooted; and 60 per cent of the heels rooted. In R. I. No. 3 solution for 43 hours the following per-

TABLE I—EFFECT OF SYNTHETIC GROWTH SUBSTANCE ON VARIOUS TYPES OF ARCTOSTAPHYLOS UVA-URSIS CUTTINGS

Type of Cutting	Solution Used	Length of Treatment (Hours)	Number Cuttings	Number Rooted	Dead* or Not Rooted	Per Cent Rooted**	Remarks on Root Formation
Multiple terminal	A No. 3	24	15	13	2	87	Very good roots
Single terminal	A No. 3	24	15	11	4	73	Fair roots, near base
Cut single terminal†	A No. 3	24	15	0	15	0	No roots
Heel.....	A No. 3	24	15	8	7	53	Fair roots, near base
Multiple terminal	R. I. No. 3	24	15	13	2	87	Excellent roots
Single terminal	R. I. No. 3	24	15	12	3	80	Best on terminals
Cut single terminal	R. I. No. 3	24	15	4	11	27	Few, near ground line
Heel.....	R. I. No. 3	24	15	12	3	80	Good roots, near base
Multiple terminal	A No. 3	43	15	12	3	80	Excellent, well distributed
Single terminal	A No. 3	43	15	9	6	60	Fair, scattered
Cut single terminal	A No. 3	43	15	5	10	33	Spurge, above base
Heel.....	A No. 3	43	15	9	6	80	Fair, at base
Multiple terminal	R. I. No. 3	43	15	14	1	93	Excellent, well distributed
Single terminal	R. I. No. 3	43	15	9	6	60	Spurge, near base and ground line
Cut single terminal	R. I. No. 3	43	15	6	9	40	Spurge, near base
Heel.....	R. I. No. 3	43	15	10	5	67	Good, at base
Multiple terminal	A No. 4	24	10	10	0	100	Excellent, well distributed
Single terminal	A No. 4	24	10	8	2	80	Very good
Cut single terminal	A No. 4	24	10	0	10	0	No roots
Heel.....	A No. 4	24	10	7	3	70	Very good
Multiple terminal	R. I. No. 4	24	10	9	1	90	Excellent
Single terminal	R. I. No. 4	24	10	4	6	40	Spurge
Cut single terminal	R. I. No. 4	24	10	0	10	0	No roots
Heel.....	R. I. No. 4	24	10	8	2	80	Very good
Multiple terminal	A No. 4	43	10	9	1	90	Excellent
Single terminal	A No. 4	43	10	6	4	60	Fair
Cut single terminal	A No. 4	43	10	6	4	60	Fair, best of cut terminals
Heel.....	A No. 4	43	10	8	2	80	Very good

\*What appeared to be basal stem rot, may have accounted for some of the dead plants.

\*\*Five plants used as check for each type of cutting; none rooted.

†Single terminals with about 1 inch of the tip removed.

centages rooted: 93 with multiple terminals; 60 with single terminals; 40 with the single terminals with cut tips; and 67 with the heels.

There was very little difference with regard to the two solutions used, with the exception that the multiple terminals in the R. I. solution produced 93 per cent as compared with 80 per cent in A solution.

It is readily seen that the percentage of the rooted multiple terminals greatly exceeded that of the single terminals, and in turn the single terminals without cut tips produced more rooted cuttings than those with the tips removed. The heel cuttings were about equal with the single terminals, but were considerably higher in percentage than the cuttings with tips removed.

The main difference occurring in varying lengths of treatment of the No. 3 solutions was the fact that the 43-hour treatment was more effective than the 24-hour treatment on the cut terminals and a greater percentage rooted.

Where the stronger solutions were used, that is, A No. 4 and R. I. No. 4, and the cuttings treated for 24 hours, it was found that in solution A 100 per cent of the multiple terminals; 80 per cent of the single terminals; 70 per cent of the heels; and none of the terminals with tips cut off, rooted. When treated with R. I. No. 4, 90 per cent of the multiple terminals; 40 per cent of the single terminals; 80 per cent of the heels; and again none of the single terminals from which the tips had been removed, rooted. In cases where No. 4 solutions had been used for a 24-hour treatment, the results do not vary much except with the single terminals, where 80 per cent rooted in solution A and 40 per cent in R. I. solution No. 4. The different type cuttings show again that the three types without cut ends were quite superior to the single terminals which had their tips cut off and even the stronger solutions did not seem to stimulate root formation with them when the bases were immersed for 24 hours.

The 43-hour treatment with A No. 4 produced 90 per cent rooted cuttings with the multiple terminals; 60 per cent with single terminals; 60 per cent of the single terminals with about 1 inch of the tips removed; and 80 per cent where heel cuttings were used. Similarly as above, the multiple terminals produced the largest percentage of rooted plants. The single terminals were no higher in percentage than the cut terminals. This is the first instance where this has occurred. It is thought that the cuttings took up enough of the synthetic growth substance to replace that which was lost by removal of the tips and upper leaves.

In all cases the multiple terminal cuttings developed the greatest percentage of rooted plants. They produced more excellent, well distributed roots than on any other type of cutting (Figs. 1 and 2). It is believed that this is due to more natural auxin being contained in the additional tips and foliage.

The single terminals were in some, but not in all cases superior to heel cuttings in quantity rooted (Table II); for example, in Rhode Island No. 3 for 43 hours, the percentage was 67 for heels and 60 for single terminal cuttings; in R. I. No. 4 for 24 hours it was 80 for heel cuttings and 40 for single terminals; and in A No. 4 for 43 hours the

TABLE II—PERCENTAGE OF ROOTED CUTTINGS WITH VARIOUS TREATMENTS

Type of Cutting	Solution Used						
	A No. 3	R. I. No. 3	A No. 3	R. I. No. 3	A No. 4	R. I. No. 4	A No. 4
	24 Hours	24 Hours	43 Hours	43 Hours	24 Hours	24 Hours	43 Hours
Multiple terminal.....	87	87	80	93	100	90	90
Single terminal.....	73	80	60	60	80	40	60
Cut single terminal.....	0	27	33	40	0	0	60
Heel.....	53	80	60	67	70	80	80

percentage was 80 for heel cuttings and 60 for the single terminals. It was rather expected that the single terminals might produce a greater percentage of rooted plants than the heels, which, as previously mentioned, were lateral shoots. These results appear to be somewhat contrary to what might be expected, as according to Thimann and Went (9) who state that "there is a distinct correlation between the position of an organ and its auxin production; only the most apical regions form auxin, and the more terminal their position the greater their production." However, the fact that *Arctostaphylos* is a prostrate growing plant may have some bearing on these cases where the lateral shoots produced higher percentage of rooted cuttings than the terminals.

The single terminals from which 1 inch of the tip had been removed were in all cases exceedingly inferior to the other types of cuttings except where the strongest auxin solution and the longest treatment was used; that is, in A No. 4 for 43 hours. Here the percentage was the same as with the single terminals when treated in a similar manner, but with all the other treatments there was either no roots or they were sparse, scattered, or near the ground line. The best roots produced on the single terminals occurred where the strongest solutions, R. I. No. 4 and A No. 4 were used.

From the above results it appears that auxin is produced in the leaves and tips; that synthetic growth substance in solution added to the bases of cuttings for certain lengths of time add to or supplement the auxin that is naturally present and that the combination or addition of this growth substance greatly hastens and stimulates root formation by migrating and concentrating at the base of the cutting to help stimulate cell division and the formation of roots.

In commercial practice it is not uncommon that propagators, in order to reduce leaf surface to avoid too rapid transpiration from cuttings, will remove considerable leaf surface and in many cases the tips of the cuttings and tips of the leaves. In light of the above findings it would seem advisable, in some cases, to retain as much of the tip, leaves, and tips of leaves as is practically possible, since it seems that these areas are the ones that contain the most natural auxin which will help stimulate root formation.

#### SUMMARY AND CONCLUSIONS

From the results obtained in this experiment it is evident that *Arctostaphylos uva-ursi* responded quite readily to treatments with

indolebutyric acid. From 80 to 100 per cent rooted cuttings were obtained by using different concentrations for different periods of time on multiple terminals; 80 per cent rooted cuttings were secured with treated single terminals; 80 per cent with heel cuttings; and in one case, as high as 60 per cent was obtained with single terminals from which the tips had been removed. The fact that the multiple terminal cuttings were the first to develop roots would seem to indicate that they contained more natural auxin than the other cuttings that had less tips and leaves.

The multiple terminal cuttings in all cases, developed the greatest percentage of rooted plants and the quantity and quality of roots was better than on any other type of cutting. In general, the least response was from the cuttings which had the upper leaves and tips removed and the greatest response was obtained from the cuttings which had the most foliage and tips intact. The heel cuttings and lateral shoots, in some cases, gave higher percentage of rooted cuttings than the single terminals. There was apparently very little difference in the results obtained from the two stock solutions used; the main difference occurred in the concentration of the solution; the length of treatment and the type of cutting. Cutting off 1 inch of the tip appears to remove considerable natural auxin, that probably would aid in root formation.

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## Propagation of *Sciadopitys Verticillata* with Root-Inducing Substances<sup>1</sup>

By J. A. DeFRANCE, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

METCALFE (4), Secretary of Plant Hormone Committee, Kew, England, gives a tentative list of plant species difficult to propagate vegetatively. *Sciadopitys verticillata* is included in this list. He says, "These were selected after consulting several nurserymen, as well as those responsible for propagating plants at the Royal Horticultural Society gardens at Wisley, and the Royal Botanic Gardens, Kew." Tincker (5) gives a list of species difficult to propagate (including *Sciadopitys verticillata*), cuttings of which have so far refused to root in spite of treatment with growth substances.

Hitchcock and Zimmerman (3) treated cuttings of *Ilex* and *Taxus* with preparations of indolebutyric, indoleacetic, indolepropionic, and naphthaleneacetic acids and induced earlier rooting, and also increased the number of roots as compared with control cuttings. DeFrance (2) by the aid of growth substances secured 80 per cent rooting of *Daphne cneorum* and 100 per cent *Taxus cuspidata* in 6 weeks time. Chadwick (1) reports indolebutyric acid as giving best results in most cases when compared with indoleacetic, naphthaleneacetic, and phenylacetic acid when treating cuttings of ornamental plants.

Cuttings 4 to 5 inches long were taken January 29 from plants about 3 feet tall. Some of these were placed in A No. 3 solution which was made by adding 1 quart water to 5 cubic centimeters of a commercial root-inducing preparation. Another batch of cuttings was treated in a water-solution of indolebutyric acid stock solution labelled R. I. solution No. 1. The stock solution was made by dissolving 500 milligrams of indolebutyric acid crystals in 120 cubic centimeters of 38 per cent ethyl alcohol. One quart of water was added to 5 cubic centimeters of the concentrate to make the indolebutyric acid-water solution which was called R. I. No. 3. This is approximately the equivalent of 5 cubic centimeters to 1000 cubic centimeters or 2 milligrams indolebutyric acid to 100 cubic centimeters of water. The cuttings were treated for 20 hours in these solutions by immersing the bases to a depth of 1 inch. Five cuttings were not treated with any phytohormone material, but the bases were immersed in water for the same length of time that the other cuttings were treated.

After the 20-hour treatment, the cuttings were placed in an open bench in the Floricultural greenhouse where there was bottom heat applied electrically. The temperature was maintained at approximately 76 degrees F. Most of the time the greenhouse temperature was the same as that of the bench. The rooting medium consisted of a mixture of one part peat moss and three parts sifted coal cinders from which the fine dust-like material had been removed. This made a fairly coarse textured medium.

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The cuttings examined March 4 were found to be well callused but there was no sign of roots. On April 18 the space in the Floricultural greenhouse was needed for other purposes, so the cuttings were removed to a bench in the Experiment Station greenhouse where there was no bottom heat and placed in a mixture of one part sand and three parts peat moss. Roots about 1 inch long were noted on some of the

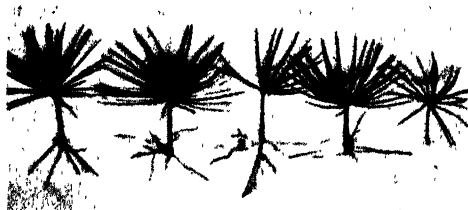


FIG. 1. Effect of root inducing substances on cuttings of *Sciadopitys verticillata*. Left to right, the first two were treated with solution A No. 3 (1 quart water added to 5 cubic centimeters commercial root inducing substance); the next two were treated with R. I. solution No. 3 (1 quart water added to 5 cubic centimeters stock solution indolebutyric acid or approximately 2 milligrams per 100 cubic centimeters water; and the last one, without roots, is one of the control plants (no treatment).

cuttings at that time. On July 17 the cuttings were dug. The rooted cuttings were potted. All the others had well developed calluses and were re-treated in their respective solutions and reset in the bench. These were examined September 15. The results obtained are shown in Table I. Fig. 1 shows some of the cuttings that had rooted by July 17.

The results of this experiment show that it is possible to root cuttings of *Sciadopitys verticillata* by the aid of root growth substances. Seventy per cent rooted

cuttings were obtained by the use of indolebutyric acid solution. There was very little apparent difference in the quality and quantity of roots formed with regard to the two solutions used.

TABLE I—EFFECT OF ROOT-INDUCING SUBSTANCES ON CUTTINGS OF *SCIADOPITYS VERTICILLATA*

Treatment	Number of Cuttings	Well Rooted July 17	Well Rooted September 15	Slightly Rooted September 15	Died	Per Cent Rooted
R. I. No. 3	10	3	2	2	1	70
A No. 3	10	3	1	1	1	50
Check	5	0	0	0	1	0

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# The Effect of Synthetic Growth Substances on the Rooting and Subsequent Growth of Ornamental Plants

By L. C. CHADWICK and D. C. KIPLINGER, *Ohio State University, Columbus, Ohio*

SINCE the recent discovery by Zimmerman and Wilcoxon (8) of the effectiveness of indolebutyric and other acids on root initiation, the Floriculture Division of Ohio State University has been conducting experiments to determine the value of these synthetic growth substances to the commercial field of ornamental horticulture.

## MATERIALS AND METHODS

The synthetic growth substance crystals were obtained from the Pennsylvania Chemical Company, Ambler, Pennsylvania. The dusts, Auxan and Rootone, were obtained from the Chemicals Limited, Montreal, Canada, and the American Chemical Paint Company, Ambler, Pennsylvania, respectively. Distilled water used in the preparation of the solutions was obtained from the Ohio State University chemical laboratory and had a pH of 5.8 as shown by tests on a Leeds and Northrup potentiometer. The plant materials were obtained from the campus of Ohio State University and from local greenhouses and nurseries.

The desired solutions were prepared by dilutions from a stock solution stored in the dark at room temperatures. The stock solution was prepared by dissolving 1 gram of indolebutyric acid in 125 cubic centimeters of 95 per cent ethyl alcohol and adding enough distilled water to bring the volume of the solution up to 250 cubic centimeters. The strength of this stock solution was 4 milligrams per 1 cubic centimeter. The diluted solutions were used only once, though preliminary tests showed they could be used several times.

Softwood cuttings of greenhouse and woody plant material were handled in the usual commercial manner. Leaf areas were kept at a maximum as better rooting responses were obtained than when leaf areas were materially reduced. This has also been reported by Zimmerman (7). After the cuttings were made, they were bunched, held with a rubber band, and placed in drinking glasses containing 100 cubic centimeters of the desired solution. About 1 to 1½ inches of the basal part of the cuttings were immersed. The glasses containing the cuttings were placed in the propagation house. All cuttings tested were soaked for 24 hours in the indolebutyric acid solutions. Soaking untreated cuttings in water resulted in rotting of the basal end, and since commercial methods were employed at all times, untreated cuttings were placed in the desired medium as soon as made.

When the cuttings were removed from the solutions, they were placed immediately into a greenhouse bench containing sand or a mixture of two parts sand and one part peat by volume, which had been previously steam sterilized. Cuttings were inserted in the media in the

accepted commercial manner as recommended by Laurie and Chadwick (3). All cuttings were rooted in a north lean-to which was heavily shaded with whitewash during the summer and was provided with electric cables thermostatically controlled at 74 degrees F for bottom heat. Air temperatures varied from 10 to 15 degrees lower in the cool months, and the relative humidity was between 60 to 80 per cent. The usual care was given the cuttings during the rooting period.

## RESULTS

*Hardwood Cuttings*.—On November 25, 1937, 280 *Ligustrum vulgare* cuttings were tied in bundles of 10 and the basal 2 inches of each bundle was placed in a pot of moist German peat moss. The pot was placed in a closed case where the temperature was maintained between 80 degrees F and 84 degrees F and the relative humidity at 90 to 100 per cent. Ten cuttings were removed from the peat moss every day, and they were soaked 24 hours in a solution of indolebutyric acid at 5 milligrams per 100 cubic centimeters. Following this treatment the cuttings were inserted in sand in the closed case. In conjunction with these cuttings, 20 cuttings from similar *Ligustrum* plants were taken each day for 30 days, 10 of them being soaked in a 5 milligram per 100 cubic centimeters solution of indolebutyric acid, the other 10 receiving no treatment. These cuttings were also placed in sand in the closed case. On February 5, 1938, all cuttings were removed, and the results recorded.

In all cases of comparison of the various treatments, untreated cuttings rooted best. A comparison of the rooting percentages before and after the time of callusing (December 8, 1937) showed that the factor of callusing did not affect rooting. This is not in accord with Stoutemyer (6) who worked with locust cuttings taken in the spring. It is possible that 80 degrees F was too high for a storage temperature.

Hardwood cuttings of the Barbara Ecke poinsettia taken in January showed an increase in the rooting percentage over the period of time the cuttings were in the bench when treated with 1, 3, or 5 milligrams of indolebutyric acid.

*Softwood Cuttings, Greenhouse Plants*.—One claim for synthetic growth substances is their influence on the rooting percentage of cuttings. A number of greenhouse plants were tested by treatments with dusts and various concentrations of indolebutyric acid and results were compared with those of untreated cuttings. The treated cuttings rooted in greater percentages than untreated cuttings over the period of time the cuttings were in the bench. This is another way of stating that the time required to reach the normal rooting percentage was decreased. Dusts were slightly inferior to solutions in the percentage rooted but gave much better rooting percentages than untreated cuttings.

Skinner (5) has reported that the quality of the root system is improved when cuttings are treated with indolebutyric acid. Tests were conducted to determine the quality of root systems induced by the commercial dusts.

Dusts have one desirable advantage over solutions in that they can be used on cuttings of such plants as poinsettia, lantana, and so on,

that are very subject to rot when soaked. The greatest disadvantage of dusts is the difficulty of increasing the concentration of growth substance. It can be partially accomplished by wetting the basal end of the cuttings before dusting as this materially increases the amount of dust that adheres.

In Table I are shown results tabulated from observations on *ageratum*, *centaurea*, *feverfew*, *lantana*, *poinsettias*, and *scarlet plume* cuttings taken in August and September, 1938. Since these plants exhibit similar rooting habits, the data is collective.

TABLE I—COMPARISON OF THE QUALITY ROOT SYSTEMS PRODUCED ON UNTREATED AND DUSTED SOFTWOOD CUTTINGS OF SOME GREENHOUSE PLANTS

Treatment	Quality of Root System (Per Cent)			Total Rooted (Per Cent)
	Good	Poor	None	
Check . . . . .	27	44	29	71
Auxan . . . . .	45	37	18	82
Rootone . . . . .	60	30	10	90

It is readily seen that the use of dusts resulted in an increase in the percentage of cuttings possessing a good root system, although the results are not as striking as when solutions are used.

Due to inconvenience experienced in soaking the basal ends of cuttings, an effort was made to find some other method of treatment that could be used commercially. Cuttings of *chrysanthemums* were stuck in sand and sprayed once with indolebutyric acid at 10 milligrams per 100 cubic centimeters and three times with a 2 milligram per 100 cubic centimeter solution. Since preliminary tests showed that 100 per cent rooting may be obtained in 14 days by soaking the basal ends of *chrysanthemums* for 24 hours in indolebutyric acid at 0.25 milligram per 100 cubic centimeters, spraying was found not to be as effective in inducing roots as was the standard soaking method. Smaller rooting percentages were obtained and more growth substance was used when the cuttings were sprayed.

*Softwood Cuttings, Woody Plants:*—Similar studies have been made on softwood cuttings of over 100 woody ornamental plants. The results obtained substantiated those observed with cuttings of greenhouse material in that the time required to reach the normal rooting percentage was decreased and better quality root systems were obtained.

Treatment of cuttings of *Cornus florida rubra*, the Red Flowering Dogwood, for 24 hours in 1 milligram per 100 cubic centimeters solution of indolebutyric acid gave 90 per cent rooting in 6 weeks while untreated cuttings gave negative responses. Normally this plant is not propagated by cuttings, although it has been rooted successfully without the aid of growth substances. Tests with *Hydrangea petiolaris* showed that treatments with 1, 2, and 4 milligrams of indolebutyric acid for 24 hours gave negative responses after 5 months in the cutting bench.

Chadwick (2) has reported that roots of certain plants have a definite place of protrusion. To determine the effect of indolebutyric acid on this placement of roots, cuttings of seven of these plants were treated with 1 milligram per 100 cubic centimeters. Fifteen cuttings were used per treatment. Roots on cuttings of *Caragana arborescens* were distinctly polar. Treatment with indolebutyric acid did not change this position. *Clethra alnifolia* produced more roots in vertical lines below the buds when treated. Such a mass of roots occurred at the nodal region of Forsythia cuttings that some roots actually appeared to protrude from the internode. Roots appeared in the normal position with *Physocarpus amurens* and *Ribes odoratum*. Treatment of cuttings of *Pyracantha coccinea pauciflora* neither changed the position nor the number of roots that arose. All roots arose in the axil of the bud or thorn. Thirty per cent of the Ginkgo cuttings rooted at the second node from the base when treated, while untreated cuttings exhibited basal rooting only. Other tests showed that 1 milligram per 100 cubic centimeters was too strong for Ginkgo and hence the treated basal portion of the cutting was probably not the physiological base.

*Narrowleaf Evergreens*.—The distribution of roots on cuttings of narrowleaf evergreens was observed and results of tests on *Juniperus chinensis pfitzeriana* are shown in Table II.

TABLE II—PERCENTAGE OF ROOT DISTRIBUTION ON *Juniperus chinensis pfitzeriana* CUTTINGS FROM THE BASE UP IN CENTIMETER INCREMENTS

Treatment in Milligrams / 100 Cubic Centimeters	Centimeters from the Base									
	1	2	3	4	5	6	7	8	9	10
Check . . . . .	84	11	—	5	—	—	—	—	—	—
IB 1* . . . . .	79	16	4	—	1	—	—	—	—	—
IB 3 . . . . .	52	32	9	5	2	—	—	—	—	—
IB 5 . . . . .	60	16	10	9	4	1	—	—	—	—
IB 10 . . . . .	40	18	14	13	9	4	2	—	—	—
IB 15 . . . . .	29	27	18	14	7	4	1	—	—	—

\*IB 1—One milligram of indolebutyric acid per 100 cubic centimeters.

In general as the concentration passed the optimum, part or all of the soaked basal end became inactivated resulting in fewer roots being produced on this portion of the stem, but larger numbers further from the base of the cutting. This had been previously noticed on softwood cuttings of greenhouse and woody ornamental plants.

The effect of indolebutyric acid on the rooting percentage, number and length of roots was studied, and data are presented in Table III.

With *Juniperus chinensis pfitzeriana* and *Thuja plicata atrovirens* the use of indolebutyric acid resulted in greater rooting percentages over the length of time the cuttings were in the bench and increased the average number of roots per cutting. There was no apparent relation between the number of roots induced and their length. Biale and Halma (1) have reported similar results. It is interesting to note that the use of high concentrations of growth substance when the plants had almost passed their rest period (January) resulted in a larger number of roots being produced than either in November or Decem-

TABLE III—THE EFFECT OF TREATMENT WITH INDOLEBUTYRIC ACID ON THE ROOTING OF CUTTINGS OF SOME NARROWLEAF EVERGREENS AFTER 3 MONTHS

Date	Treatment (Milligrams per 100 Centimeters)	Average Number of Roots per Cutting	Average Total Length of Roots per Cutting (Centimeters)	Rooted (Per Cent)
<i>Juniperus chinensis pfitseriana</i>				
November 18	Check	1.22	18.64	10
November 18	IB 5	4.18	12.68	42
November 18	IB 10	3.92	12.95	51
November 18	IB 15	2.75	9.33	27
December 19	Check	2.20	15.27	6
December 19	IB 5	4.93	17.11	19
December 19	IB 10	6.81	14.91	20
December 19	IB 15	5.70	17.33	13
January 21	Check	1.44	16.15	11
January 21	IB 5	12.35	25.18	58
January 21	IB 10	19.67	18.32	45
January 21	IB 15	14.75	22.59	70
February 24	Check	1.00	140.00	5
February 24	IB 1	7.00	47.97	65
February 24	IB 3	8.93	25.67	75
February 24	IB 5	6.50	62.91	70
<i>Thuja plicata atrovirens</i>				
November 21	Check	3.70	26.78	31
November 21	IB 5	9.42	21.65	65
November 21	IB 10	12.84	12.52	63
November 21	IB 15	15.47	13.43	48
December 20	Check	15.75	16.47	13
December 20	IB 5	8.83	13.30	58
December 20	IB 10	14.09	19.49	55
December 20	IB 15	11.64	16.35	52
January 20	Check	5.86	32.93	23
January 20	IB 5	6.84	34.04	55
January 20	IB 10	4.73	31.65	50
January 20	IB 15	13.63	33.83	63
February 24	Check	3.00	31.39	30
February 24	IB 1	5.64	68.76	63
February 24	IB 3	4.29	51.42	70
February 24	IB 5	4.50	53.89	60
<i>Taxus cuspidata</i>				
November 20	Check	6.10	15.22	60
November 20	IB 5	5.69	14.57	44
November 20	IB 10	9.04	15.16	60
November 20	IB 15	9.04	13.99	69
December 16	Check	3.63	12.33	45
December 16	IB 5	4.33	7.18	23
December 16	IB 10	5.72	7.02	45
December 16	IB 15	6.42	5.71	48

ber. Reducing the concentration of February cuttings resulted in a decrease in the number of roots induced but higher percentages of rooting. It follows that the time of taking the cuttings will result in variation of the response to growth substances. The length of the roots induced was independent of the concentration used, but the length increased as the season passed.

With *Taxus cuspidata* growth substances did not increase the percentage rooting in a 3 months period, nor was the number of roots induced significantly increased.

Treatment of cuttings of *Juniperus virginiana keteleeri* failed to give a response that was commercially significant. *Juniperus virginiana cannarti* failed to root or callus when treated with either indolebutyric or naphthaleneacetic acid. Untreated cuttings callused but did not root in a three months period.

**Broadleaf Evergreens:**—Tests were conducted with *Pyracantha coccinea pauciflora* using 5, 10, and 15 milligrams per 100 cubic centimeters of indolebutyric acid and 200, 700, and 1100 parts per million of nitrogen in the form of urea, alone and in all possible combinations. Five and 10 milligrams solutions increased the percentage rooting in a 2 months period when used alone or in any combination with urea. The 15 milligrams solution and concentrations of urea alone resulted in rotting of the basal ends. The use of indolebutyric acid on *Pyracantha* was of little value commercially since the increased percentage rooting was small and no better quality root system can be expected.

Cuttings of *Azalea kurume* were treated with commercial dusts and solutions of indolebutyric acid at 0.5, 1, and 2 milligrams per 100 cubic centimeters. Rootone gave 94 per cent rooting in 65 days, untreated cuttings rooting 61 per cent. Soaking the cuttings promoted rotting which reduced the percentage rooting.

**Miscellaneous Tests. Treatment of Rose Stocks:**—The purpose of this test was to determine the effect of indolebutyric acid on the development of new roots. It is generally thought the development of a good root system is associated with greater percentages of successful grafts. Roots of rose stocks (*Rosa manetti*) were soaked 24 hours in 3 milligrams of indolebutyric acid per 100 cubic centimeters, and the stocks were potted in standard 2½ inch pots. Treatments and data recorded are shown in Table IV.

TABLE IV—THE EFFECT OF TREATING ROOTS OF *Rosa Manetti* (AMERICAN) STOCKS ON THE QUALITY OF THE ROOT SYSTEM PRODUCED

Treatment	Quality of Root Systems (Per Cent)								
	5 Days in Greenhouse			10 Days in Greenhouse			15 Days in Greenhouse		
	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor
Check	33	52	14	32	60	7	45	51	4
Indolebutyric acid 3 milligrams per 100 cubic centimeters	20	55	21	24	65	10	31	62	6

In the case of each time period before placement in a grafting case more good root systems were produced on untreated stocks than on treated stocks. Also in each of the three time periods, fewer fair and poor root systems were produced by untreated stock plants. Records of successful grafts showed 65 per cent "take" on treated rootstocks and 75 per cent on untreated stocks.

**Root Cuttings:**—Pink *Bouvardia hybrida* was used to determine the effect of indolebutyric acid on root cuttings. Fifty cuttings were made for each of the four treatments shown in Table V, the treated cuttings being soaked 24 hours.

After 10 weeks no more growing points appeared, and final data were taken. The use of indolebutyric acid depressed the production of shoots from root cuttings. The greater the concentration, the fewer the number of growing points appeared. Inhibition of buds has been reported by Pearse (4).



TABLE V—THE EFFECT OF VARIOUS CONCENTRATIONS OF INDOLEBUTYRIC ACID ON THE SHOOT PRODUCTION OF BOUVARDIA ROOT CUTTINGS

Treatment	Number Planted	Date Planted	Per Cent of Root Cuttings Forming Growing Points (Cumulative)									
			Number of Weeks After Treatment									
			1	2	3	4	5	6	7	8	9	10
Check	50	December 24	-	-	-	-	-	24	50	94	94	94
Indolebutyric acid 1 milli-gram per 100 cubic centimeters	50	December 24	-	-	-	-	-	2	10	36	36	36
Indolebutyric acid 3 milli-grams per 100 cubic centimeters	50	December 24	-	-	-	-	-	-	-	2	2	2
Indolebutyric acid 5 milli-grams per 100 cubic centimeters	50	December 24	-	-	-	-	-	-	-	-	-	-

*Subsequent Growth After Rooting:*—Tests on pompom varieties of chrysanthemums showed that treatment of cuttings with growth substances did not result in any increase in yield over untreated cuttings. Growth observations on ageratum and poinsettias showed that if treated and untreated cuttings were removed from the propagation bench at the time the untreated cuttings had rooted, the ultimate growth was the same.

#### SUMMARY

Soaking the basal ends of cuttings gave more satisfactory results than spraying with solution of growth substances. Hardwood cuttings of *Ligustrum vulgare* did not respond favorably to indolebutyric acid applied either before or after callusing when stored at high temperatures. Treatment of softwood cuttings of greenhouse and woody ornamental plants and cutting of narrowleaf evergreens with synthetic growth substances decreased the time required to reach the normal rooting percentage. The final rooting percentage was not increased.

The quality of the root system produced on softwood cuttings by treatment with growth substances was superior to the root systems on untreated cuttings over the period of time the cuttings were in the bench. The use of growth substances in the majority of cases caused more roots to be produced over a larger stem area. Apparently no relation existed between the number of roots induced and their length. The external position of the roots on plants which exhibit specific rooting habits was not changed by applications of growth substances.

Treatment of roots of plants gave variable responses, in general causing a decrease in the root production. Plants normally propagated by softwood cuttings were rooted in less time than was usual for the species. In general plants normally difficult to propagate by cuttings, as for example, *Juniperus virginiana cannarti*, *Juniperus virginiana ketelceri*, and *Hydrangea petiolaris*, were not benefited by treatment.

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# Talc as a Carrier of Substances Inducing Root Formation in Softwood Cuttings

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**P**RACTICAL use of growth substances in aqueous solutions for rooting cuttings with unskilled personnel is impeded by the diversity of concentrations required and by the difficulty of providing storage for large quantities of cuttings while undergoing treatment. For these reasons, the greater simplicity of application and increased latitude in permissible dosages reported by Grace (1) where talc is used as a carrier warrant careful appraisal of this vehicle for the consideration of conservationists, nurserymen and others interested in large-scale propagation by cuttings.

## MATERIALS AND METHODS

*Preparation of Dusts and Solutions:*—The preparation of the various talc dust mixtures used in these experiments differed from the "grinding mix" method described by Grace (1). Crystals of the growth substance were dissolved in sufficient 95 per cent ethyl alcohol to make a pasty mixture when stirred into pharmaceutical talc, costing 25 cents per pound. The mixture was dried in the dark with a fan circulation of unheated air, and stirred occasionally with a glass rod during the period of drying. When dry, the mixture formed a powder free from lumps. All dusts were stored away from light and heat in closed glass containers.

The aqueous solutions were prepared from concentrated alcoholic solutions of the crystalline substances in the usual manner and all aqueous treatments lasted 24 hours.

*Propagation Methods:*—A rather liberal application of the dust was given to the cuttings, previously moistened with a bulb spray. If the cuttings were dripping wet, the dust became pasty and difficult to use. The cut basal ends were plunged, several at a time, into the dusts to a depth of about 1 centimeter. Excess powder was removed by a light shaking or tapping. The cuttings were inserted at once in sand, in greenhouses provided with outside wood lattice shade and additional cloth shade within. The usual maximum light intensity on the cuttings at noon on a clear day in August or September ranged between 200 to 400 foot candles as read on a Weston illumination meter. A bottom heat of 65 to 70 degrees F was maintained in the propagating beds by means of thermostatically controlled electrical heating cables.

## RESULTS

*Data on Rooting with Various Concentrations of Growth Substance:*—The plants used in our trials were so selected as to include species

<sup>1</sup>Report of cooperative research between the Section of Hillculture Research, Soil Conservation Service and the Division of Plant Exploration and Introduction, Bureau of Plant Industry, United States Department of Agriculture.

requiring widely different dosages with the aqueous treatment. The rooting responses with indole butyric acid are shown in Table I, and similar trials with naphthalene acetic acid are reported in Table II. The concentration of the latter substance is more critical in aqueous treatments.

TABLE I—A COMPARISON OF ROOT STIMULATION IN SOFTWOOD CUTTINGS USING VARIOUS CONCENTRATIONS OF INDOLE BUTYRIC ACID IN AQUEOUS SOLUTIONS AND IN TALC DUST (DUPLICATE TRIALS OF 25 CUTTINGS PER LOT, RESULTS ARE REPORTED IN PERCENTAGES ROOTED)

Subject	Rooting Period	Check	Check (Talc)	Aqueous Treatments for 24 Hours			Talc Dust Treatments		
				5 Ppm	20 Ppm	60 Ppm	1 to 4000	1 to 1000	1 to 250
<i>Actinidia arguta</i> ..	September 13 to October 12	48 36	—	76* 96*	64 84	8† 44†	44 64	84* 80*	28† 24†
<i>Chrysanthemum morifolium</i> ..	August 24 to September 10	64 48	— 80	84* 80*	60† 60†	72† 60†	80 76	72* 88*	80† 84†
<i>Dianthus gallicus</i> ..	September 21 to October 11	36 12	36 12	80* 76*	44† 40†	44† 60†	16 56	56* 88*	68† 72†
<i>Diervilla floribunda</i> ..	September 20 to October 5	0 12	44 36	88* 88*	84* 76*	52† 84†	36 64	72* 60*	64* 80*
<i>Abelia</i> hybrid ( <i>A. grandiflora</i> X <i>A. Schumannii</i> )	September 25 to October 6	4 8	—	80 64	80* 76*	44† 48†	40 0	60 16	80* 6*
<i>Jasminum</i> sp. ..	September 30 to November 9	52 68	60 72	48 52	48* 52*	28† 60†	60 20	60 20	44 52
<i>Lagerstroemia indica</i> ..	September 16 to October 24	48 12	—	8 40	52* 28*	32† 8†	40 36	56* 64*	20† 32†
<i>Pachysandra terminalis</i> ..	August 26 to September 24	48 40	—	56 68	100* 88*	68 92	92 84	96 96	100* 96*
<i>Callicarpa dichotoma</i> ..	August 25 to September 13	80 64	— 100	100* 100*	100* 100*	100* 100*	76 92	96* 96*	100* 100*
<i>Euonymus americana</i> ..	September 3 to October 5	92 60	—	96* 96	96* 100*	100* 96*	72 72	96 88	100* 88*
<i>Euonymus japonica</i> ..	August 24 to September 24	48 28	—	92 76	100* 100*	100* 96*	88 80	76 84	96* 100*
<i>Euonymus japonica</i> ..	September 22 to October 18	36 48	48 48	88 88	92* 92*	100* 96*	72 40	68 76	88* 88*
<i>Ligustrum compactum</i> ..	September 21 to October 24	16 0	32 72	24 12	24 20	68* 48*	20 44	36 24	32* 40*
<i>Ligustrum ovalifolium</i> ..	August 25 to September 25	56 68	—	76 84	76 76	84* 80*	80 64	72 36	76* 48*

\*Indicates treatment causing formation of heavy root systems on cuttings

†Indicates injury to cuttings, probably due to over-dose of growth substance.

Indications are given of the variations in heaviness of rooting with different treatments because the less concentrated dusts often induced high percentages of rooting, though the roots formed were weak or no better than those of the untreated checks.

Toward the end of these tests the fact was apparent that many species would stand dusts even more concentrated than 1 to 250, and the test plants were tried again with 1 to 100 dusts of both indole-butyric and naphthalene acetic acids. The results were practically

TABLE II—A COMPARISON OF ROOT STIMULATION IN SOFTWOOD CUTTINGS USING VARIOUS CONCENTRATIONS OF NAPHTHALENE ACETIC ACID IN AQUEOUS SOLUTIONS AND IN TALC DUST (DUPLICATE TRIALS OF 25 CUTTINGS PER LOT, RESULTS ARE RECORDED IN PERCENTAGES ROOTED)

Subject	Rooting Period	Check	Check (Talc)	Aqueous Treatments for 24 Hours			Talc Dust Treatments		
				5 Ppm	20 Ppm	60 Ppm	1 to 4000	1 to 1000	1 to 250
<i>Actinidia arguta</i>	September 13 to October 12	48 36	— —	84* 76*	72† 68†	28† 8†	72 52	64* 68*	32† 44†
<i>Dianthus gallicus</i>	September 21 to October 11	36 12	36 44	40* 32*	24† 36†	0† 0†	56 72	40* 56*	36† 36†
<i>Diervilla floribunda</i> . . . . .	September 20 to October 5	0 12	44 36	80* 80*	24† 32†	0† 0†	60 40	56 40	60* 44*
<i>Jasminum sp.</i> . . . . .	September 30 to November 9	52 68	60 72	48 48	44* 64*	36† 60†	88 76	92* 92*	84 64
<i>Abelia</i> hybrid ( <i>A. grandiflora</i> × <i>A. Schumannii</i> )	September 23 to November 1	36 32	28 60	76 48	88* 80*	24† 68†	52 36	28 40	76* 40*
<i>Ligustrum compactum</i> . . . . .	September 21 to October 24	16 0	32 72	16 32	28* 24*	20 12	64 56	72 64	64* 52*
<i>Euonymus japonica</i> . . . . .	September 22 to October 18	36 48	48 48	64 56	64* 72*	68* 64*	64 68	84 84	96* 80*

\*Indicates treatment causing formation of heavy root systems on cuttings.

†Indicates injury to cuttings probably due to overdose of growth substance.

identical with both substances. Nearly all cuttings of *Abelia*, *Actinidia* and *Diervilla* were killed, but those of *Pachysandra*, *Euonymus* and *Ligustrum* were not injured. Surprisingly, *Dianthus* and *Chrysanthemum* gave 100 per cent rooting without the slightest sign of toxicity, although these plants are very sensitive to strong dosages in aqueous solutions. In a previous trial of rooting some definite signs of toxicity had appeared in the 1 to 250 dusts with the two latter. Toxicity resulting from too high concentrations of growth substances was not consistent in repeated trials and apparently varies with many factors both in the cutting and in the propagation conditions. Tabulation of rooting is complicated by the occasional occurrence of injury at the base of well rooted cuttings along with the formation of unusually heavy roots.

Trials conducted on a less extensive scale with dusts of methyl indole butyrate and potassium naphthalene acetate gave results similar to those obtained with indolebutyric acid and naphthalene acetic acid.

Our results show that the dust treatment is, in general, as effective as the aqueous solution treatments. The statement of Grace (1) that there is greater latitude of dosages with dusts than with solutions is supported by this investigation. This is shown particularly in cases where cuttings were killed by high concentrations of naphthalene acetic acid in aqueous solution, but were not injured with high concentrations in dust form. Nevertheless, despite the greater latitude, varying optimum concentrations were evident as with the aqueous solutions.

The dusts were noticeably effective in promoting rooting even at the low concentration of 250 parts per million (1 to 4,000) though the resulting roots were scanty. This concentration was definitely much

too low. The 1 to 2,000 dusts were effective although not as reliable as the concentration of 1,000 parts per million (1 to 1,000). This latter concentration was satisfactory for general use though our experiments show the frequent desirability of higher concentrations. 1 to 500 dusts were also tried with satisfactory results. The dusts having a concentration of 4,000 parts per million (1 to 250) were exceedingly effective, but caused injury to cuttings of a few sensitive species. This toxicity, however, was often inconsequential, even on some subjects which are considered to require very low dosages of growth substances, such as *Chrysanthemum* and *Dianthus*.

No one dust can be ideal for use with all cuttings, but satisfactory compromises are possible. The 1 to 1,000 concentration seems to be a close approximation to a single general purpose dust.

*Rooting of Difficult Subjects with Dusts:*—Dust applications gave outstanding results with some very difficult subjects. Unfortunately, cutting wood was too scarce with these species to permit trials of rooting on the scale described above. The use of naphthalene acetic acid at 1 part per 1,000 in talc induced root formation on cuttings of refractory species such as *Disanthus cercidifolius*, *Trema* sp. and *Ilex vomitoria*, which rarely form roots without treatment. Using the same dust, a propagator at this station, Mr. Martin Bilon, rooted cuttings of *Dipelta yunnanensis*, *Cornus kousa* and *Sycopsis sinensis* and found that with other difficult species the time of rooting was reduced nearly one-half.

*Addition of Accessory Substance:*—Several substances which have been used to break dormancy in plants were incorporated with the dusts containing growth substances. The addition of thiourea gave particularly consistent and promising results which are presented in Table III. The numerical counts suggest, rather than prove, definite increases in rooting due to the thiourea, but the increased heaviness in rooting was quite unmistakable in some lots. In no case was the substance deleterious although the concentrations may have been far from optimal. Cuttings of difficult subjects including *Disanthus cercidifolius* and *Trema* sp. formed much heavier roots with this combination than with naphthalene acetic acid alone. This again may be only coincidence. Since Hitchcock and Zimmerman (3) have found that alcohols may increase the effectiveness of growth substances in treatments, there seems to be ample justification for further investigation of various accessory substances.

Attention may be drawn at this point to the indications, shown in the data in Tables I, II, and III, that talc alone frequently increased the percentage though it seems not to affect the heaviness of rooting.

*Importance of Details in Use of Dusts:*—The importance of apparently trivial details was illustrated by an experiment in which the cuttings were set in both wide and narrow trenches in the sand. The narrow trench was of the type formed by many propagators who open the trench in the sand with a knife. Some of the dust is inevitably rubbed off the cuttings in inserting them in such a narrow fissure. The wide trench was made with a wood label approximately 1 centimeter thick. Some of the cuttings were treated by applying the dust

TABLE III—THE EFFECTS OF TALC DUSTS WITH NAPHTHALENE ACETIC ACID ALONE AND IN COMBINATION WITH THIOUREA (DUPLICATE TRIALS OF 25 CUTTINGS PER LOT, RESULTS ARE RECORDED IN PERCENTAGES ROOTED)

Subject	Rooting Period	Check	Check (Talc)	Naphthalene Acetic Acid 1 to 1000	Naphthalene Acetic Acid 1 to 1000 Plus 0.5 Part Thiourea	1 to 1000 Dust of Three Parts Naphthalene Acetic Acid Plus 1 Part Thiourea
<i>Actinidia arguta</i> . . . . .	August 10 to September 10	20 24	— —	44 84	— —	84* 80*
<i>Actinidia arguta</i> . . . . .	September 13 to October 12	44 56	28 40	64 68	72* 96*	— —
<i>Abelia</i> hybrid ( <i>A. grandiflora</i> X <i>A. Schumannii</i> ) . . . . .	September 23 to November 1	36 32	28 60	28 40	80* 48*	64* 58*
<i>Dianthus gallicus</i> . . . . .	September 21 to October 11	36 12	36 44	40 56	64* 52*	— —
<i>Diervilla floribunda</i> . . . . .	September 20 to October 5	0 12	44 36	56 40	72* 92*	— —
<i>Euonymus americana</i> . . . . .	September 3 to October 5	60 60	56 64	76* 92*	80* 56*	84* 84*
<i>Euonymus japonica</i> . . . . .	September 22 to October 18	36 48	48 48	84* 84*	96* 96*	— —
<i>Ligustrum compactum</i> . . . . .	September 23 to October 21	40 52	— —	56 60	— —	88* 58*

\*Indicates treatment causing formation of heavy root systems on cuttings.

carefully to the cut basal surface only. The others were treated by dipping the ends of the cuttings in the dust to a depth of about 1 centimeter. The results as shown in Table IV indicate the desirability of applying the dust freely along the base and also of precautions to prevent loss of the powder while inserting the cuttings in the propagating bench.

TABLE IV—ROOTING OF CUTTINGS OF EUONYMUS JAPONICA UNDER VARIOUS CONDITIONS, TREATED WITH 1 TO 1,000 INDOLE BUTYRIC ACID TALC DUST (ROOTING PERIOD OCTOBER 5 TO NOVEMBER 1, RESULTS ARE GIVEN IN PERCENTAGES, 25 CUTTINGS PER LOT ROOTED)

Type of Trench	Place of Application of Dust	Well Rooted	Lightly Rooted	Not Rooted
Narrow	Only at basal cut surface	12	24	64
Narrow	Only at basal cut surface	8	20	72
Narrow	At basal cut and along stem to 1 centimeter above base	24	40	36
Narrow	At basal cut and along stem to 1 centimeter above base	24	40	36
Wide	Only at basal cut surface	40	20	40
Wide	Only at basal cut surface	40	44	16
Wide	At basal cut and along stem to 1 centimeter above base	48	28	24
Wide	At basal cut and along stem to 1 centimeter above base	64	24	12

*Stability of Dust Preparations:*—The relative stability of the various growth substances when mixed with talc or other dust carriers will be an important factor in practical usage. Dusts containing indole acetic acid quickly develop a pink color, probably caused by an oxidative change to urososein. This reaction in the presence of a nitrite and a

mineral acid is described by Hawk and Bergeim (2) as a standard physiological test in urinalysis. Dusts containing either indolebutyric acid or methyl indole butyrate turn brownish with exposure to light. No color changes have been noticed in dusts containing naphthalene acetic acid or potassium naphthalene acetate. Possibly the naphthalene compounds are the more stable of the growth substances. Unfortunately, very little information on this important matter is available.

*Advantages of the Dust Treatment:*—A. The cost is very low, as the amount of dust used per cutting is very small. In our trials, slender cuttings such as *Ligustrum* or *Euonymus* required from 10 to 15 grams of the dust per 1,000 cuttings, while thicker ones such as *Actinidia* required from 15 to 25 grams per 1,000. The amount of dust adhering depended to some extent upon the moisture present. In general, 1 pound of dust might be expected to treat at least 20,000 to 40,000 cuttings. B. The saving of time is very great as the dust is quickly applied. The cuttings may be inserted at once into the propagating bed. C. The method is simple and requires no apparatus. Charts of dosages are not essential. The treatment is safe in the hands of inexperienced workmen. D. The method is exceedingly effective in practice. Hastening of rooting, increase in size of root system, and percentage of survival are equal or even superior to the results obtainable with solutions. The solution treatment may be retained for certain special cases, though our results show the high efficiency of the dust method with exceedingly difficult subjects.

Finally, further study may show that the higher concentrations usable may make dusts more effective than solutions with some particularly difficult material.

#### ACKNOWLEDGMENTS

Grateful acknowledgment is made to Dr. H. G. du Buy and Mr. Franklin D. Jones for suggestions regarding the use of thiourea in dusts. This investigation was conducted with the active cooperation of the Section of Hill Culture Research of the Soil Conservation Service. Thanks are due the head of the section, Mr. S. B. Detwiler, for supplying materials and the assistance of his staff member, Mr. F. L. O'Rourke.

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# Three Year Studies in the Behavior of Twenty-one Chrysanthemum Clons Flowering at Different Seasons

By FURMAN LLOYD MULFORD, *U. S. Department of Agriculture, Washington, D. C.*

**I**N breeding chrysanthemums, it is important to know to what extent a group of clons will vary in time of bloom from year to year. Also, when selections are to be made among a group of new seedlings for earliness of flowering, what assurance there is that time of bloom will be constant from year to year. In addition, when old plants are propagated by cuttings, will the new plants bloom at the same time as the parent stock? In 1936 an experiment with 21 chrysanthemum clons was designed to furnish some data on the first of these problems. In 1938 an additional experiment was run to secure data on the third.

## MATERIALS AND METHODS

The 21 clons used were selected from seedlings developed in the chrysanthemum breeding program at Arlington Farm. Included among these were some that flowered sufficiently early to be regarded as possibly desirable for introduction as garden varieties in the northern sections of the country and some that were considered to be too late for these regions.

The plants were propagated early in the spring of 1936 and field plots were arranged in a modified Latin square. Twelve rooted cuttings of each clon were planted in each of five blocks, making 60 plants of each. The rows were 4 feet apart with a spacing of 18 inches between plants in the row. Since in 1937 it became necessary to provide for cultivation at right angles to the 1936 planting, the clumps were lifted in the early spring and replanted in the same field and in the same arrangement. In 1938 the plants were not disturbed.

When five to six flowers were fully opened a plant was recorded as in bloom. In all instances such plants continued to bloom profusely. Since some clons bloomed as early as July, the first day of this month was selected as the zero point, and the days to bloom were computed from this date.

There is considerable difference in time of bloom between certain clons and some of them also vary from year to year. This is shown in the means given in Table I. Variance analysis of the data showed that a difference of more than 7 days between varieties or between years is significant.

The clons in Table I are arranged in the order of blooming in 1936. In the succeeding years very few maintained the same rank. For instance, the mean blooming date for clon 24 was September 19 in 1936 and 1937, and September 28 in 1938. During the same years its rank was 6th, 14th, and 14th, respectively. Clon 15, on the other hand, bloomed on September 28 in 1936, August 15 in 1937, and on July 30 in 1938. During these years its rank was 13th, 2nd, and 5th.

A glance at the table reveals that in general the earlier blooming clons of 1936 showed the greatest variability in time of bloom in the

TABLE I—COMPARISON OF TIME OF BLOOM OF 21 CHRYSANTHEMUM CLONS OVER A 3-YEAR PERIOD\*

Order of First Bloom	Clon Number	1936	1937	1938
1	19	August 27	August 12	July 19
2	14	September 7	August 22	August 10
3	9	September 10	August 17	August 2
4	20	September 18	September 3	September 8
5	11	September 19	August 21	July 17
6	24	September 19	September 19	September 28
7	22	September 22	September 6	August 26
8	5	September 23	August 17	July 30
9	3	September 24	September 7	September 13
10	13	September 25	September 1	August 31
11	7	September 26	August 16	July 30
12	18	September 26	September 16	September 28
13	15	September 28	August 15	July 30
14	4	October 2	September 19	September 28
15	16	October 6	October 15	October 8
16	21	October 7	October 14	October 12
17	23	October 9	September 4	September 24
18	12	October 11	October 6	September 24
19	17	October 12	October 18	October 19
20	10	October 12	October 21	October 17
21	2	October 14	October 20	October 15
Mean	—	September 27	September 23	September 6

\*Differences of more than 7 days are significant for both varieties and years.

next 2 years. In the entire lot of 21 there are three, numbers 21, 17, and 2, that show no significant variation in time of bloom from year to year. A few others, numbers 3, 10, 12, 13, 16, 24, and 20, show no difference between 2 of the 3 years. All the others show a very great difference in bloom from year to year. The mean blooming date of clons 19, 14, 9, 11, 22, 5, 7, and 15 becomes earlier each year, while in 18, 4, and 23 it fluctuates from late to early to late.

In 1938, single shoots were removed from the old plants and were planted in a similar layout adjacent to the old planting. This made it possible to compare the time of bloom of old established plants with new propagations from them. The results of the variance analysis of the data are shown in Table II. As noted at the bottom of the table, differences of more than 10 days between old and new plants are significant.

In the right-hand column of Table II the plus signs indicate relatively later blooming of the young plants and the negative, relatively early. Not all of these differences, however, are significant. In general, propagations from early flowering old clons were later flowering than the parent stocks. In all there were 11 propagations that bloomed later than the parent plants, but three of these, numbers 13, 3, and 12, were not significantly later. Of the nine that bloomed earlier only two, numbers 18 and 24, were significantly so. One, number 4, was the same in both ages.

Some interesting similarities in flowering response of the same clons are shown in a comparison of Tables I and II. With but two exceptions (numbers 4 and 9), the clons showed a similar shift in time of bloom when older plants were compared with younger, and when established plants were compared with current season propagations. Both propagations of clon 4 bloomed at the same time in 1938.

TABLE II—COMPARISON BETWEEN OLD AND NEW CHRYSANTHEMUM CLONS FOR TIME OF BLOOM (1938)\*

Order of Bloom	Clon Number	Old Plants		New Propagation	
1	11	July	17	August	20 +
2	19	July	19	August	8 +
3	7	July	30	September	2 +
4	5	July	30	September	13 +
5	15	July	30	September	15 +
6	9	August	2	July	25 —
7	14	August	10	September	2 +
8	22	August	26	September	12 +
9	13	August	31	September	7 +
10	20	September	8	September	6 —
11	3	September	13	September	18 +
12	12	September	24	October	1 +
13	23	September	24	October	10 +
14	18	September	28	September	6 —
15	24	September	28	September	12 —
16	4	September	28	September	28 0
17	16	October	8	October	2 —
18	21	October	12	October	7 —
19	2	October	15	October	12 —
20	10	October	17	October	15 —
21	17	October	19	October	15 —
Mean	—	September 6		September 16	

\*Differences of more than 10 days between clons of old and new propagation are significant.

### CONCLUSIONS

The results of this experiment indicate at least two types of chrysanthemums with respect to blooming period. In one, exemplified by clon number 2, there was no difference in the time of bloom over the 3-year period nor in the comparison of old plants versus new propagation. The second type, illustrated by clon 7, showed a wide variation in bloom from year to year and between old plants and new cuttings.

In general, chrysanthemums have been considered sensitive to short photoperiods, and shading is commonly practiced to bring them into bloom early. Since there is very little fluctuation in total daylight from year to year, it would be expected, if photoperiod was the only factor, that a chrysanthemum variety would bloom at approximately the same time year after year. From the data presented in this paper, however, it would appear that in some varieties there are factors other than photoperiod which are important in the control of time of bloom. It may be that earliness and lateness may represent different rates of development after flower primordia are differentiated. One factor which does fluctuate considerably from year to year is temperature, and even though flower buds are initiated, their rates of development may vary with a high or a low temperature.

## A Statistical Study of Doubleness in Nasturtium

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### ABSTRACT

This paper will be published in full in the *Journal of Heredity*.

THE inheritance of doubleness in the nasturtium is complicated by some type of modification which controls the degree of expression of the recessive double gene. From a cross between a double (with mean petal number of 9.5 +) and a single (with 5 petals) there have been derived in subsequent inbred generations new intermediate, true breeding races with mean petal numbers of 5 +, 6 +, 7 +, and 8 +. When continuous backcrosses have been made to the recessive double, the mean petal number has been increased as backcrossing has continued, until it has attained the value of the double parent. This has sometimes occurred in the second backcross, but more often in the third.

This behavior indicates either modifying factors or that the double gene can not fully express itself unless it is present in the double genotype.

# Effect of Growth Substances and Maturity on Rooting of Cuttings of Certain Shrubs<sup>1</sup>

By L. E. LONGLEY, *University of Minnesota, St. Paul, Minn.*

THIS paper will deal with two different factors which have influence on the ultimate rooting of greenwood cuttings of certain shrubs and trees: (a) The influence of the use of Auxilin on the rooting of greenwood and leaf-bud cuttings, and (b) the influence of the relative maturity of cuttings on their rooting.

## INFLUENCE OF AUXILIN ON THE ROOTING OF CUTTINGS

A number of workers have reported on the use of various growth-promoting substances or hormones. In this experiment Auxilin was used at the dilution No. 3 recommended by the manufacturers. This dilution provides approximately 2.2 milligrams of indolebutyric acid per 100 cubic centimeters of water. The procedure followed was the usual one of setting the trimmed cuttings upright in a container with the solution about 1 inch deep. The checks were put in the sand bench at once after trimming. The treated cuttings were allowed to stay in the solution for 20 hours and then inserted in the sand.

Leaf-bud cuttings were made of *Prunus tomentosa*, *P. padus*, *P. triloba plena*, *P. hybrid*, Newport Plum, *Syringa japonica*, *Rhodotypos kerrioides*, *Rubus deliciosus*, and *Sambucus racemosa laciniata*. With the latter variety, three groups were made as follows: (a) the cuttings from the upper three nodes, (b) those from the second three nodes, and (c) those from the third three nodes.

Most of these plants were in an active growing condition. This was particularly true of the Elder. However, with *Prunus padus*, the most active period of growth was past. The date of making these cuttings was July 6, 1938.

Table I gives the results of the treatments. It will be noted that in the case of some of the species, preliminary notes were taken to ascertain whether the speed of rooting was accelerated by the use of Auxilin. These cuttings were taken out and notes made; then all cuttings were reinserted in the sand bed to remain until the time of the final count.

## INFLUENCE OF THE RELATIVE MATURITY OF CUTTINGS ON THEIR ROOTING

Hitchcock and Zimmerman (1) using cuttings from different parts of the stem as well as heel and mallet cuttings found that sometimes the upper cutting was best, but sometimes some other portion, and sometimes even the heel or mallet cutting was best. The following tests furnish some data along similar lines.

*One-eye Cuttings from Different Regions of the Current Year's Growth:*—Table II and the data for *Sambucus racemosa laciniata* in

<sup>1</sup>Paper No. 1667 of the Journal Series of the Minnesota Agricultural Experiment Station. Completion of certain parts of this paper was made possible by personnel of Works Progress Administration Official Project 465-71-3-350.

TABLE I—ROOTING OF GREENWOOD STEM AND LEAF-BUD CUTTINGS TREATED WITH AUXILIN (CUTTINGS MADE JULY 6, 1938)

Kind	Number in Check	Number in Treated	Per Cent Rooted in Preliminary Notes†		Final Per Cent Rooted		
			Check	Treated	Check	Treated	
Leaf-Bud Cuttings							
<i>Prunus tomentosa</i> . . . . .	55	55	—	—	0	34.5	
<i>Prunus hybrid</i> Newport Plum . . . . .	29	29	—	—	0	6.8	
<i>Syringa japonica</i> . . . . .	36	36	—	—	0	0	
<i>Prunus padus</i> . . . . .	31	17	—	—	0	0	
<i>Prunus triloba plena</i> . . . . .	20	20	—	—	0	0	
<i>Rhodotypos kerrioides</i> . . . . .	27	27	—	—	0	33.3	
<i>Rubus deliciosus</i> . . . . .	0	0	—	—	0	0	
<i>Sambucus racemosa laciniata</i>							
From upper 3 nodes* . . . . .	55	55	9.1	91.00	80	100.0	
From 2nd 3 nodes . . . . .	55	55	5.4	40.00	14.5	54.5	
From 3rd 3 nodes . . . . .	55	55	0	18.10	1.8	25.4	
Greenwood Stem Cuttings							
<i>Ribes Alpinum variegatum</i> . . . . .	50	50	30.0	74.00	60.0	92	
<i>Prunus padus</i> . . . . .	31	17	0	29.40	32.6	52.9	
<i>Prunus triloba plena</i> . . . . .	24	25	0	40.00	0	56.0	

\*The tip bud was discarded in each case.

†Preliminary notes were taken on *Ribes Alpinum variegatum*, *Prunus padus*, and *P. triloba plena* on July 29, on *Sambucus racemosa laciniata*, on August 12.

Table I show the effects of the relative maturity of cuttings on their rooting. The three plants which were used represent three totally different types of wood. *S. racemosa laciniata* represents rather tender greenwood; *Vinca major variegata*, partly-ripe greenwood, and *Parthenocissus quinquefolia* dormant hardwood.

TABLE II—ROOTING OF ONE-EYE CUTTINGS FROM SUCCESSIVE PARTS OF THE STEM. CUTTING NO. 1 MEANS THE CUTTING JUST BELOW THE TIP CUTTING

Cutting Number	<i>Vinca major variegata</i>		<i>Parthenocissus quinquefolia</i> *	
	Number	Per Cent Rooted	Number	Per Cent Rooted
Tips . . . . .	71	38	28	11
1 . . . . .	71	32	28	68
2 . . . . .	71	46	29	76
3 . . . . .	71	58	25	56
4 . . . . .	71	68	29	79
5 . . . . .	71	75	29	55
6 . . . . .	71	75	31	79
7 . . . . .	71	77	31	68
8 . . . . .	71	68	26	46
9 . . . . .	71	55	24	54
10 . . . . .	71	52	24	46
11 . . . . .	—	—	23	39
12 . . . . .	—	—	20	45
13 . . . . .	—	—	15	47
14 . . . . .	—	—	12	25

\*These were dormant stems.

*Layered Cuttings of Hedera Helix*:—Table III gives the data for rootings of layered cuttings of *Hedera helix*. The following types of layered cuttings were used: (a) Tip layers about 6 inches long in active growth; (b) sections of stem, about 8 to 12 inches long just back of the point where the tip layers had been taken off having practically

TABLE III—ROOTING OF *Hedera helix* LAYERED CUTTINGS

	Number of Cuttings	Per Cent Rooted
Tip layers.....	44	83
Layers with leaves, tips removed.....	96	47
Hard layers, very few leaves.....	97	50
Hard layers without leaves.....	30	8

their full complement of leaves; (c) older sections with relatively few leaves remaining; and (d) still older hard layers without leaves.

This table indicates that the tips are best for rooting; that the older wood, as long as it possesses any appreciable number of leaves is not so good, but is still of considerable value as propagation material, and that the old stems that have lost their leaves are of little value for propagation.

*Influence of Age of Wood on Rooting of Cuttings:*—In general, it is usually recommended that cuttings should be made of comparatively young wood, usually of the current season's growth. In Table IV is given some data for three species in which 1-, 2-, and 3-year-old woods were used. Of these *Chimaphila umbellata* (pipsissewa) is interesting. This is a little broad-leaf evergreen ground cover found in woods on acid, sandy soil. The 2-year-old wood of this plant is markedly the best with the 1-year-old wood fairly good. The 3-year wood is much slower to root and gives fewer rooted cuttings. *Taxus canadensis* does not show much difference in actual percentage of rooting. Although the 3-year wood shows a slightly lower percentage of rooting, the roots are, in general, longer and more numerous. The fact that a 3-year cutting is larger, with more stored food, gives it an advantage resulting in a larger plant. With *Juniperus canadensis depressa* the 1-year wood rooted slightly better, with the 3-year wood somewhat poorer, and the 2-year wood still poorer. In view of the larger plants obtained from the older wood, however, it is often desirable to use 2- or 3-year-old wood of this plant unless the 1-year wood is very large.

TABLE IV—INFLUENCE OF AGE OF WOOD ON THE ROOTING OF CUTTINGS

Kind	Cuttings					
	1-Year		2-Year		3-Year	
	Number	Per Cent Rooted	Number	Per Cent Rooted	Number	Per Cent Rooted
<i>Chimaphila umbellata</i> .....	146	45.2	236	51.7	156	34.9
<i>Taxus canadensis</i> .....	604	78.3	600	76.6	600	73.3
<i>Juniperus communis depressa</i> ...	75	92.0	150	84.0	125	89.6

### DISCUSSION

The data in Table I indicate that the use of Auxilin to promote rooting in leaf-bud cuttings of certain shrubs, mostly hard to root, had no apparent effect with *Syringa japonica*, *Prunus padus*, *P. triloba plena*, and *Rubus deliciosus*; with *P. hybrid*, Newport plum, there was some increase in the percentage of rooted cuttings and consider-

able effect with *P. tomentosa* and *Rhodotypos kerrioides*, while with *Sambucus racemosa laciniata*, there was still greater increase in rooting especially with harder wood. With stem cuttings of *P. padus* and *Ribes alpinum variegatum*, there was an appreciable increase in rooting due to the use of Auxilin, while *P. triloba plena* showed a very great increase in rooting. The speed of rooting was also greatly increased in the case of *S. racemosa laciniata*, *Ribes Alpinum variegatum*, *P. padus* and *P. triloba plena*.

Leaf-bud cuttings of *Sambucus racemosa laciniata* rooted better when the three youngest nodes were used, the second three nodes rooted only fairly well, and the third three nodes very poorly. With one-eye cuttings of *Vinca major variegata* vines, the best rooting occurred at about the upper limit of the lower third of the vine, dropping off from this towards the base and tip. With hardwood, one-eye cuttings of *Parthenocissus quinquefolia*, a similar but not so significant tendency was observed (see Table II).

With layered cuttings of *Hedera helix*, any cutting with leaves showed some rooting, the best area being the upper 6 inches (Table III).

When 1-, 2-, and 3-year-old cuttings were used of *Taxus canadensis*, *Juniperus communis depressa* and *Chimaphila umbellata*, fair to good rooting was obtained at all ages. With *Taxus canadensis* and *Juniperus communis depressa*, the 2- or 3-year-old wood was preferable in view of the stronger, larger plants obtained.

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## Studies of the Pollen of the Perennial Phlox

By THELMA B. POST, *U. S. Horticultural Station, Beltsville, Md.*

A LARGE collection of perennial phloxes has been assembled at the United States Horticultural Station, Beltsville, Maryland, for work on the Septoria leaf spot of this popular perennial. Miss Lingard is the only resistant variety so far observed. Unfortunately it is highly sterile, which may make it very difficult to transmit its resistance to new varieties. A comparative study of the pollen of Miss Lingard and of the other phlox varieties available was undertaken to see if it might show any reason for this sterility and also serve as a preliminary survey in preparation for a program of breeding for resistance to the leaf spot disease.

### POLLEN COLLECTIONS

Pollen from 55 plants was collected and fixed in a 3:1 mixture of absolute alcohol and acetic acid. After 24 hours in the fixative it was transferred to 70 per cent alcohol, where it remained until slides were made. Preparations were stained in aceto-carmin and the cover glass sealed to the slide with a paraffin and beeswax mixture. Counts were made of 100 pollen grains chosen at random to determine the percentage of abortive and good pollen. Since in germination tests run on all the varieties, plump grains had germinated, they were counted as good, while the empty or shriveled ones and those that did not stain readily were classed as abortive. These counts were made within a few days of the collections.

The percentage of bad grains was high in most of the varieties, ranging from 1 per cent in Border Queen to 94 per cent in Fiancee and Champs Elysees. Miss Lingard had only 36 per cent abortive pollen. Of the other varieties with which some crosses have already been attempted, Tapis Blanc had 67 per cent abortive pollen, Mrs. Jenkins 70 per cent, and Debs 32 per cent.

### DIAMETER<sup>1</sup> AND VARIABILITY OF POLLEN

The variation in size between the pollen grains of the different varieties is not large, but there are many significant differences. The variety Isabey has the smallest mean,  $42.0 \pm 1.59$ , while Electra has the largest,  $59.7 \pm 2.06$ .

The variability in size of the pollen within the varieties of perennial phlox examined shows wide differences. These grade from E. J. Far-  
rington with a coefficient of variability of  $32.174 \pm 3.277$ , down to George Stipp with a coefficient of variability of  $5.28 \pm .077$ . Most of the variabilities are high and it does not appear that the percentage of bad pollen and the coefficient of variability are correlated. For instance, Isabey, with only 8 per cent bad pollen has the high variability of  $26.833 \pm 2.683$ , while Albion, with 42 per cent bad pollen, has a low variability of  $9.613 \pm .961$ .

<sup>1</sup>Measurements are in microns and are based on a sample of 50 grains of each of the varieties.

It should be added here that while the percentages of bad pollen were computed within a few days of the pollen collections, the measurements of the pollen grains were made after the pollen had been stored in alcohol for several months. At the end of this period the grains stained much more readily, and while every effort was made to measure only plump grains that were normal in appearance, some grains formerly counted as abortive because they did not stain readily may have been included in the measurements.

### CONCLUSION

While the work reported here is only exploratory and preliminary in character, several interesting points have appeared. One is the possibility of using Miss Lingard, a variety resistant to leaf spot, as a pollen parent in our breeding program. Crosses have already been made and a few seed secured, one of which had germinated before this paper was completed. Further crosses are being attempted, using chiefly those varieties which have a fairly high amount of good pollen. Another is the confirmation of the extremely hybrid character of the summer perennial phlox.

## Comparative Study of Pollen of *Lilium Longiflorum* Varieties

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**S**TUDIES made on pollen grains in some species of plants have indicated that variation in their size is correlated, in general, with the number of chromosomes. Variable sizes are taken to indicate irregularities in meiosis. The relationship of abortive or "bad" pollen to fertility is also one that has been considered, sometimes with varying results. For instance, Poole (3) found in a *Crepis* hybrid a high correlation between percentage of good pollen and fertility, while Mulford (2) reported no such correlation in *Chrysanthemum*. Possibly sterility factors or some form of incompatibility may be present.

An examination of pollen characteristics in Easter lily (*Lilium longiflorum* Thunb.) is of interest in connection with breeding, disease, and other investigations now in progress on this species at the United States Horticultural Station, Beltsville, Maryland. The varieties of Easter lily available were Creole, Croft, Erabu, Giganteum, Harrisii, and White Queen. The Creole variety is apparently a clonal line, uniformly self sterile, and shows varying amounts of irregularity at first metaphase of pollen mother cells. All the other varieties named contain self fertile individuals and each variety appears to include more than one clonal line. The name Croft has been applied for convenience to an unnamed stock in commercial use in Oregon. White Queen is an unselected group grown from seed furnished under that name.

The pollen characteristics determined were percentage of good pollen grains, mean size, and variability of size. The variation of these pollen characteristics within varieties, between varieties, between self fertile and self sterile individuals, between healthy and diseased plants, and between plants found to be regular and irregular at first meiotic metaphase, was then considered. Nineteen plants of Creole, 9 of Croft, 18 of Erabu, 13 of Giganteum, 17 of Harrisii, and 6 of White Queen, were included in the study. Pollen collections, one from each plant, were made in the greenhouse from March through May, 1938.

### TECHNIQUE

The anthers were collected just before dehiscence and fixed in a 3:1 mixture of absolute alcohol and acetic acid. After 24 hours in the fixative they were transferred to 70 per cent alcohol where they remained until slides were made. Preparations were stained in acetocarmine and the cover glass sealed to the slide with a mixture of paraffin and beeswax. Counts were made of 100 pollen grains chosen at random to determine the percentage of abortive and good pollen. Germination tests were run on pollen of practically all varieties and since the large plump grains germinated readily they were counted as good, while empty or shriveled ones were classed as abortive.

A photomicrograph was made of a representative field on each slide. One was also made, using the same magnification, of a stage microme-

ter. Later the prints, each of pollen from a different plant, were projected on a screen and 25 normal random grains measured by means of the print of the stage micrometer.

### PERCENTAGE OF ABORTIVE POLLEN

Abortive pollen is remarkably high in *Harrisii* (Table I), the mean percentage falling at  $44.82 \pm 2.02$ . The variation about this mean is apparently continuous. The abortive pollen was always of a peculiar elliptical shape in this variety. There is nothing to indicate that the percentage of defective pollen is affected by virus infection. Four plants which had been examined cytologically and found very regular at first meiotic metaphase showed percentages of abortive pollen characteristic of the variety. The high incidence of pollen abortion in *Harrisii* is evidently not traceable to meiotic irregularities.

TABLE I.—PERCENTAGE OF ABORTIVE POLLEN, MEAN POLLEN GRAIN DIAMETER, COEFFICIENT OF VARIATION OF POLLEN GRAIN DIAMETER, IN SIX VARIETIES OF EASTER LILY (WITH STANDARD ERRORS OF THE STATISTICS AND RANGE OF OBSERVATION)

Variety	Abortive Pollen Grains		Mean Diameter		Coefficient of Variation of Pollen Grain Diameter	
	Mean and Standard Error	Range	Mean and Standard Error	Range	C.V. and Standard Error	Range
<i>Harrisii</i> . .	$44.82 \pm 2.02$	31 to 56	$94.1 \pm 2.2$	78.0 to 110.2	$13.27 \pm 1.43$	8.25 to 23.57
<i>Creole</i> . . .	$10.74 \pm 2.16^*$	1 to 28	$78.5 \pm 2.3$	63.2 to 96.8	$10.49 \pm .73$	6.77 to 21.03
<i>Erabu</i> . . .	$6.81 \pm 1.07^\dagger$	3 to 16	$84.5 \pm 1.9$	70.8 to 102.4	$13.33 \pm 2.01$	5.97 to 40.85
<i>Croft</i> . . .	$2.50 \pm 0.82^{**}$	0 to 7	$84.6 \pm 2.1$	74.4 to 94.4	$11.20 \pm 1.59$	6.01 to 23.02
<i>White Queen</i> .	$6.33 \pm 2.49$	1 to 17	$88.0 \pm 1.4$	81.8 to 91.6	$10.47 \pm .92$	6.02 to 22.36
<i>Giganteum</i> . .	$4.08 \pm 0.84$	2 to 12	$86.7 \pm 1.8$	76.0 to 98.8	$10.69 \pm 1.50$	5.62 to 23.58

\*These fall into two groups: Seven plants average  $22.14 \pm 1.76$  per cent; 12 average  $4.08 \pm 4.3$  per cent.

\*\*Excluding one plant with 51 per cent.

†Excluding two plants with 50, 54 per cent.

In the *Creole* variety the mean percentage of bad pollen is  $10.74 \pm 2.16$ , but the plants examined clearly fall into two discontinuous groups. Seven plants averaged  $22.14 \pm 1.76$  per cent abortive grains, ranging from 17 to 28 per cent; the remaining 12 plants averaged  $4.08 \pm 0.43$ , and ranged from 1 to 6 per cent abortive. The occurrence of two distinct pollen groups in this variety which all available evidence indicates is a clon, is difficult to explain. Cytological observations on meiosis on *Creole* (1) have shown, however, a variable amount of irregularities from plant to plant. Moreover, plants subjected to a sudden high temperature (from 46 to 46.5 degrees C for 30 minutes) have had great differences in bivalent formations in two flowers on the same plant. There is no evident correlation between pollen abortion and the presence of disease. All members of the *Creole* clon have been found self sterile, and all examined have shown some irregularities at meiosis, but the per cent of bad pollen is not particularly high.

*Erabu* showed wide variation in aborted grains, the majority ranging from 3 to 16 per cent, but two individuals had 50 and 54 per cent respectively. Excluding these two plants, the mean for the remaining 16 plants is  $6.81 \pm 1.07$ . Since this variety is well known as a heteroge-

neous mixture of types, it is not surprising that pollen should show discontinuous variation. Seven of 18 Erabu plants were known to be self fertile, but these included one with 50 per cent bad pollen; of seven known to be self sterile, two had only 4 per cent abortive grains. Of two plants examined at meiosis, one which proved regular showed 7 per cent bad pollen, and one showing irregularity of pairing had 50 per cent aborted grains. Little importance, however, can be attached to a single pair of observations.

The Croft variety, which also contains a number of different plant types, had good pollen in general, with a mean percentage of defective grains of  $2.50 \pm 0.82$  if one divergent individual with 51 per cent bad pollen is omitted. This atypical plant happens to be self sterile, but the other self sterile individuals showed only 1 to 2 per cent defective grains. In White Queen, abortive pollen ranged from 1 to 17 per cent with a mean of  $6.33 \pm 2.49$ . Two known self sterile plants showed 10 and 17 per cent bad pollen; the first also showed some irregularity of pairing at meiosis. Four self fertile plants showed only 1 to 5 per cent defective grains.

In Giganteum 12 normal plants averaged  $4.08 \pm 0.84$  per cent defective grains, and one white margined Giganteum, a variegated form, had 15 per cent bad pollen. Within the normal group there is a suggestion of higher percentage of bad pollen in one distinctive self sterile group, but no difference in pollen quality between self sterile and self fertile plants in general.

#### DIAMETER OF POLLEN GRAINS

All varieties show variation in pollen grain diameter, but it is apparently continuous variation about the variety mean, with no clear indication of grouping. In every variety there are significant differences between the smallest and the largest plant means, and often many differences between individual plants prove to be significant. Strangely enough Creole, a clonal variety, shows as great a range in pollen size as any other variety, although Erabu, Croft, and White Queen are known from other data to be heterogeneous groups. The data show no evident relation between pollen grain diameter and percentage aborted pollen, nor any relation to self fertility or to disease.

Harrisii has the largest pollen grains, and Creole the smallest (Creole is not quite significantly smaller than Croft), the other four varieties falling into an intermediate group in which the individuals show no significant differences one from another.

#### VARIABILITY IN SIZE OF POLLEN GRAINS

The coefficients of variation of pollen grain diameter determined for individual plants show wide differences between individuals within a variety. It is frequently true that individuals which do not differ significantly in mean size of pollen grains do differ significantly in the spread of the samples about their means as measured by coefficients of variation. Such instances of relatively uniform and relatively variable populations with closely similar mean pollen diameters occur in the Creole variety as well as in the more heterogeneous varieties. The

coefficients of variability calculated for the variety groups do not differ significantly from each other.

No relation is evident in the data between variability of pollen grain size and per cent of good pollen, nor self fertility, nor presence of disease. The most variable pollen sample of all came from an apparently healthy self fertile Erabu. The variegated white margined Giganteum showed a coefficient of variation of only 8.18 per cent, lower than the mean for Giganteum.

### DISCUSSION

A high percentage of abortive pollen grains appears to be characteristic of the Harrissi variety of Easter lily, but our data indicate that the peculiarity is not related to irregularities at meiosis. Little evidence appeared in our limited data that abortive pollen, pollen size, or variability of pollen size could be correlated with meiotic irregularities or with self fertility or sterility. No evidence was found to indicate that virus diseases of lily have any effect on the pollen characteristics studied. Small but significant differences in mean pollen diameter occur between certain varieties of Easter lily.

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# Biological Activity in Steam Sterilized Soils in the Greenhouse

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## METHODS AND MATERIALS

**G**REENHOUSE soil planted in roses for two years was screened and thoroughly mixed. It was placed in six-inch clay pots and treated in a steam box April 18, 1938, as follows: Check (no treatment); 30 minutes; 1 hour; 2 hours; 4 hours; and 6 hours. In the treatment of 30 minutes, temperatures ranging from 180 to 200 degrees F were reached. The temperatures in all other treatments were between 200 and 210 degrees F. The readings were made at the time the soil was removed from the steam box.

After treatment, the pots of soil were placed on the bench in a rose house under the same moisture and temperature conditions as that required for roses. The moisture in the soil was maintained at about 35 per cent, the air temperature about 60 degrees F and the humidity about 70 per cent. No manure or unsteamed soil was added for purposes of reinoculating the steamed soils.

As nearly as possible, samples were taken each week for determining the numbers of bacteria, molds, and actinomycetes. Moisture determinations of the same samples were made by drying 10 grams of the moist soil for 8 hours in an oven at 98 degrees C.

Counts of the three types of organisms were made by the plate dilution method. Ten grams of the soil were added to 90 cubic centimeters of sterile water and dilutions made up to one million or higher if necessary. The dilutions were then plated out in duplicate, 1 cubic centimeter of inoculant to each plate.

The following media were used:

### *For bacteria (soil extract agar medium):*

Agar	12.5 gram
Glucose	1.0 gram
K <sub>2</sub> HPO <sub>4</sub>	0.5 gram
Water	900 cubic centimeters
Soil extract*	100 cubic centimeters

\*Two parts water, one part soil, sterilized.

### *For molds (starch agar medium):*

Agar	10.0 gram
Starch	10.0 gram
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	2.0 gram
K <sub>2</sub> HPO <sub>4</sub>	1.0 gram
CaCO <sub>3</sub>	3.0 gram
MgSO <sub>4</sub> ·7H <sub>2</sub> O	1.0 gram
NaCl	1.0 gram
Water	1,000 cubic centimeters

*For actinomycetes (potato starch agar medium):*

Agar	15.0 gram
Potato Starch	10.0 gram
K <sub>3</sub> PO <sub>4</sub>	1.25 gram
MgSO <sub>4</sub> ·7H <sub>2</sub> O	0.75 gram
Asparagin	0.2 gram
Water	1,000 cubic centimeters

The first plates were poured April 21 and weekly thereafter for 5 weeks. No determinations were made the next 4 weeks. The tenth week after treatment, weekly determinations were again continued until the seventeenth week after steaming. The last plates were poured on August 19.

The plates containing the various media were incubated at room temperature in the desk drawer as follows: Bacteria, 60 hours; molds, 96 hours; and actinomycetes, 144 hours.

The specific groups of organisms for each media were then counted and recorded.

## RESULTS

*Bacteria*.—The number of bacteria killed was directly proportional to the length of time the soil was steamed (Table I). The following week the bacteria in the steamed soils were far more numerous than in the untreated soil with the exception of the ½-hour treatment. Thereafter, with the exception of the first week, the bacteria in the ½-hour and 1-hour treatments remained considerably higher than those in the check for the entire seventeen weeks.

TABLE I—QUANTITIES OF ORGANISMS IN GREENHOUSE SOIL STEAMED VARIOUS LENGTHS OF TIME (BASED ON NUMBERS PER GRAM OF DRY SOIL)

Treatment	Bacteria	Molds	Actinomycetes
Check . . . . .	186,314,000	8,130,000	24,390,000
½ Hour . . . . .	7,619,000	3,148	0
1 Hour . . . . .	2,500,000	1,428	0
2 Hours . . . . .	782,000	544	0
4 Hours . . . . .	306,000	244	0
6 Hours . . . . .	50,000	0	0

In the 2-hour treatment, 12 weeks after steaming the number of bacteria approached but did not fall below the check. Five weeks later the bacteria in the steamed soil were again considerably more numerous than those in the check.

In the 4- and 6-hour treatments, 11 weeks after steaming, the numbers were either comparable to or considerably below those in the check.

The fluctuations and numbers in all the steamed soils were very great, especially during the first month after steaming. The increase ranged from two to twenty-five times greater than in the check.

*Molds*.—As with the bacteria (Table I), the number killed was directly proportional to the length of time the soil was steamed. In



later weeks, the numbers in some instances were greater and in some instances less in the soils which were steamed than in the check.

During the last few weeks of the determinations, the numbers of molds in the  $\frac{1}{2}$ -hour and 1-hour treatments remained above those in the check. In the 2-hour treatment the numbers also remained higher, but they were probably comparable to the check, the difference not being very marked.

During the last 6 weeks in the 4- and 6-hour treatments, the numbers were either comparable to or considerably below those in the check. This was especially true of the 6-hour treatment.

*Actinomycetes*.—Apparently in all soils the actinomycetes were killed or rendered inactive, at least no growth was obtained on the media used (Table I). A week after treatment, actinomycetes were observed in the check and  $\frac{1}{2}$ -hour treatment only.

They became active in all soils 2 weeks after treatment, though in general after 5 weeks the numbers had not yet approached those in the untreated soils. There were two exceptions. In the  $\frac{1}{2}$ -hour and 6-hour treatments the numbers were comparable to those in the check the fourth week but not the fifth. With this one exception, actinomycetes never were as numerous in the  $\frac{1}{2}$ -hour treatment as those in the check for the entire period of 17 weeks.

In the 1-hour treatment, the numbers did not approach those in the check until the fifteenth week after steaming. They were not as numerous thereafter.

In the 2- and 4-hour treatments, the actinomycetes either exceeded or were comparable to those in the check 10 weeks after steaming and later. The same was true of the 6-hour treatment the eleventh week and after.

## DISCUSSION

The most important change brought about by steaming soil is undoubtedly that affecting the biology of the soil. No attempt was made in these studies to identify specific organisms other than the classification into groups of bacteria, molds, and actinomycetes.

It was very noticeable at the time of counting that the various types of the three groups were very much simplified in the steamed soils. There was a very marked reduction in the number of types.

It would appear that the heat treatment made conditions very favorable for a few types rather than the entire soil population. This change has been reported by other workers (3, 4).

Of the three groups studied, the greatest increase in numbers occurred in the bacteria. The fact that the number of bacteria in treatments of 4 and 6 hours were comparable to the check after 10 or 11 weeks may be of considerable importance. If the beneficial results of steaming are due to an increase in the number of organisms, steaming periods of less than 4 hours would apparently be most beneficial. There are indications that growth promoting materials are given off in the presence of microorganisms (2, 5).

Waksman and Starkey have shown that the recovery of molds after heat treatments is much less rapid than that of bacteria (4). Later,

however, the numbers were greater in the treated soils than in the untreated.

In the studies reported in this paper, the molds remained higher after about 11 or 12 weeks in the soils steamed 2 hours and less. It is very probable that the numbers were less in the steamed soils the first few weeks and that many of the organisms counted belonged to the group of "false yeasts." This would account for the high number of "molds" recorded during the initial weeks of the study. No entirely satisfactory method for counting molds has yet been devised.

The same workers (4) have reported that actinomycetes are also at first suppressed. The same results were obtained in the studies presented here.

Data taken of chemical changes are not presented here, but it is interesting that actinomycetes began to increase about the same time after steaming that nitrates began to increase. Nelson (1) has reported that several actinomycetes are active in nitrification.

#### SUMMARY AND CONCLUSIONS

Weekly determinations of bacteria, molds and actinomycetes were made in greenhouse soil steamed various lengths of time. Under the conditions of these studies, the following conclusions seem warranted:

The numbers of bacteria and molds killed were proportional to the length of time the soil was steamed. Actinomycetes were killed or at least rendered inactive in treatments of  $\frac{1}{2}$ -hour and longer.

In weeks following steaming, the bacteria were considerably more numerous in the steamed soils than in the untreated. In later weeks the numbers in treatments of 4 and 6 hours were either comparable to or less than those in the check.

In later weeks molds were more numerous in treatments of 2 hours and less than in the check. In treatments of 4 and 6 hours the numbers were either comparable to or considerably below those in the check after 10 weeks.

In the  $\frac{1}{2}$ -hour treatment, the actinomycetes were not as numerous as those in the check. In the 1-hour treatment the numbers were comparable after 15 weeks. In treatments of 2 hours and more the numbers either exceeded or were comparable to those in the check after 10 weeks.

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## Symptoms of Boron Deficiency in the Rose<sup>1</sup>

By O. W. DAVIDSON and H. M. BIEKART, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

**D**URING late September of 1938, Briarcliff roses in a demonstration experiment at the New Jersey Experiment Station developed a type of injury which, insofar as the authors are aware, has not been described heretofore. This injury was diagnosed as being due to a deficiency of boron. The plants were growing in four plots, composed of a mixture of white quartz sand and peat. These plots yielded very well during the 1937-1938 season in comparison with 18 other plots, including two good field soils. All plots composed of artificial media received semi-weekly applications of a nutrient solution. This nutrient solution was prepared from regular commercial grades of potassium dihydrogen phosphate, calcium nitrate, magnesium sulphate, ammonium sulphate and ferrous sulphate. It is interesting to note that although no boron or manganese salts were added, no evidence of boron or manganese deficiency had been observed hitherto in any of several species of plants grown in this nutrient solution during the past 10 years.

Warington (5) showed that an increase in calcium absorption hastened the appearance of boron deficiency symptoms in broad beans. Likewise, Bobko and Belvoussev (1) reported that an excessive supply of calcium increased the demand for boron by sugar beets. In this respect, it is interesting to note that the nutrient solution used for growing the roses described in this paper was very high in calcium content.

The first signs of injury to these plants that were apparent to the observer were a dying-back of the stem tips and flowering shoots, and a necrosis of the leaf tips. This occurred late in September at a time when the plants were growing very rapidly. An examination of the roots showed that nearly all of the fleshy roots and a large portion of the fine fibrous roots were dead. It was apparent that the injury to root tissue occurred much earlier than that found in the tops.

As an aid in verifying the identity of the injury, boron was added to the nutrient solution at the rate of 2 parts per million and applied to one of the four boron-deficient plots thrice weekly for 2 weeks. Thereafter the concentration of boron was reduced to 1 part per million. By the end of the third week of this treatment, new roots were forming throughout the media, especially in the upper portions. In contrast, the plots not receiving boron showed no change in the condition of the roots. Even after 2 months, only a few new roots in the upper portion of the media were found in the boron-deficient plots. Nevertheless, these plants gave no indication of wilting, even during hot fall days when the greenhouse temperature was high. In this respect it is interesting to compare the similarity between boron and calcium deficiency symptoms. Work at the New Jersey Experiment Station has shown

<sup>1</sup>Paper of the Journal Series, Division of Horticulture, New Jersey Agricultural Experiment Station.

repeatedly that calcium-deficient peach trees are abnormally resistant to wilting despite the relatively very small size of their root systems. Brenchly and Warington (2), and Warington (5) have called attention to the close physiological association of boron and calcium.

### SYMPTOMS ON LEAVES

In the early stages of the deficiency, many of the young leaves developed more or less "burning". On some, only the tips of the leaflets died. Occasionally an entire leaflet or even an entire leaf died. The most characteristic symptoms of boron deficiency in the rose, however, appeared to be the occurrence of small, abnormally thick leaves. In many cases these leaves were somewhat cup-shaped and variously distorted. Many of the small, thick leaves that were not misshapen exhibited a faint, stippled type of mottling.

### SYMPTOMS ON PREFLOWERING STEMS

In general, the most rapidly growing shoots were most seriously affected. Although most of the injured shoots were found in the upper portion of the plant, vigorous shoots arising from any portion were likely to be affected.



FIG. 1. A, Symptoms of boron deficiency in leaves and stem of preflowering shoot. Apical meristem has been killed. B, Excessive branching of boron-deficient stem.

Many of the non-flowering shoots died back from the tip before making half an inch of new growth. Some of these shoots thickened considerably and became very stiff. They slowly developed small, abnormally thick leaves, more or less distorted in shape, and thereafter remained inactive for a month or more. Such a shoot is seen in Fig. 1. In the case of some other vegetative shoots, the apical meristems died and the shoot gradually thickened while developing a few small, leathery leaves. Again, the leaves as well as the shoots were very

stiff. Unlike boron deficient tomato and celery tissues, the stiffened rose tissue could be bent without cracking. After a period of a few days to several weeks, from one to as many as seven shoots have been observed to develop from the upper 1 to 3 inches of the original shoot. Fig. 1 shows an illustration of this tendency toward excessive branching. This has been described as a characteristic of boron deficient tomato plants by Johnston and Dore (3).

## SYMPTOMS ON FLOWERING STEMS

The effect of the deficiency upon flowering shoots was unusual and very distinct. These shoots were affected in nearly all stages of development. Soon after the deficiency symptoms first began to appear, a number of the flowering shoots died back for from 2 to 6 inches soon after the buds began to protrude beyond the calyx lobes. Longitudinal sections through such stems showed that the necrosis stopped abruptly, with no apparent abnormality in the living tissue below. Later, there was a very noticeable tendency to form numerous, small branches from the axils of leaves and bracts along the flowering stem. Such branches died before making more than  $\frac{1}{8}$  to  $\frac{1}{4}$  inch of growth. Flowering shoots thus affected were abnormally thick and stiff. Leaves which formed on the main axis of boron-deficient, flowering shoots ranged in size from very small, bract-like structures to small, thick, rigid, three-leaflet structures, and even to apparently normal leaves. The presence of apparently normal leaves on boron deficient shoots, however, was seldom observed. Many of the flowering shoots on boron-deficient plants failed to elongate normally. These shoots also were thick and stiff, and usually developed one or more of the characteristic small, thick leaves with distorted leaflets. Different manifestations of boron deficiency in flowering shoots of the rose are shown in Fig. 2.

## SYMPTOMS ON FLOWERS

A characteristic symptom of this ailment in the rose appears to be the development of a number of "bull-head" buds and flowers. Not all of the buds and flowers on boron-deficient plants are thus affected, however. Also, the so-called "bull-head" buds and flowers are known to occur on rose plants adequately supplied with boron. In the case of "bull-head"

flowers on boron-deficient plants, however, the petals were abnormally thick, rigid and always curled or rolled inward at the tips, as illustrated in Fig. 2, C. Limited observations seemed to indicate that the boron-deficient flowers were noticeably more fragrant than normal blooms. This may have been associated with a high sugar content, for Johnston and Dore (3) found a striking accumulation of sugars in boron-deficient tomato plants. As has been described previously, some of the flower buds were killed as a result of the deficiency.

About 3 to 4 weeks after the deficiency developed, plants in the untreated plots became relatively inactive and remained in this condi-



FIG. 2. A, Severe boron deficiency in flowering shoot. B, Abnormal leaf formation on flowering shoot. C, "Bull-head" flower produced on boron-deficient plant.

tion until the second week in November. Thereafter top growth was resumed gradually and new foliage and shoots were nearly free of recognizable boron-deficiency symptoms. Occasionally, however, a new shoot developed the characteristic symptoms of the deficiency. It is assumed that the renewal of growth by these plants was made possible by the liberation of boron from the breakdown of root tissue.

#### EFFECT UPON COMPOSITION

Time and available material have permitted only a meager study of the effect of boron-deficiency upon the composition of rose plants. Early in December samples of stiffened stem tips 4 to 5 inches in length and showing definite symptoms of boron-deficiency were collected along with comparable samples from healthy, soil-grown plants. This material was dried, and 5-gram portions were analyzed for boron by the quinalizarin method of Smith (4). Stem tips from healthy roses were found to contain 18 parts per million of boron, whereas 14 parts per million were found in the deficient plants. Although the boron content of the deficient plants was not very different from that found in the healthy ones, nevertheless the results agree fairly well with those reported by Woodbridge (6) for apple twigs. It may be of significance also to recall that after the second week of November, roses in the deficient plots renewed growth but developed very few abnormal shoots. It is possible, therefore, that early in the fall when most of the shoots were injured, the boron may have been more widely distributed and hence present in smaller quantities in all tissues than that found in December.

Comparisons between the boron-deficient and normal plants were made with the aid of microchemical tissue tests. These showed marked accumulations of starch and tannin in the deficient roses.

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## Foundations

### PRESIDENTIAL ADDRESS

By J. K. SHAW, *Massachusetts State College, Amherst, Mass.*

**I**T was my privilege to hear the first presidential address delivered before our Society. This was at the first Philadelphia meeting in 1904 and the speaker was our first president, Liberty Hyde Bailey, the Dean of American Horticultural Science. His subject was "What Is Horticulture?" In the course of his address he remarked "and when I am through you will doubtless say 'What is horticulture?' ". The question was discussed at later meetings but in more recent years we have ceased to consider it. Yet the question has not been answered. We are too busy working in the field and, I hope, less anxious to delimit it and to build fences so that none may trespass on our preserves and that we may not stray into those of others.

The first printed copy of our By-laws requires that the president shall "deliver an address at each regular meeting" and this is one section that has never been amended. However, in the record of a few of the earlier meetings no such address appears, perhaps because the president was absent. At Washington, in 1911, the president, Spencer A. Beach, delivered the required address entitled "Horticultural Investigation in America, Its Status and Outlook". Since then no president has escaped this punishment. If you think it is the members who are punished I merely remind you that it is because you have failed to amend or abolish this particular By-law.

A superficial survey indicates that your president is the oldest, in years, ever to occupy this honorable office. Therefore, he may be permitted to delve into ancient history and recount the happenings of his boyhood days. This Society always has been and still is, one of young men. It is characterized by the strength, vigor, and triumphant optimism of youth. May it ever be so.

The genesis of our Society lies in a letter addressed to the official horticulturists of the United States and Canada under the date of June 30, 1903. It was organized September 9, 1903, in the rooms of the old and honorable Massachusetts Horticultural Society in Boston. The writer of the letter and the moving spirit in the organization of the Society was the late Spencer A. Beach, then horticulturist of the New York Agricultural Experiment Station at Geneva, New York, and later Professor of Horticulture in the Iowa State College at Ames, Iowa. The fact that he was the founder of this Society has never been publicly recognized, and I hereby place in the record this addition to the many worthy accomplishments of Spencer A. Beach — Founder of the American Society for Horticultural Science.

The list of charter members includes the names of 53 men, 10 of which appear in the roll for 1937. There are eight charter members still actively engaged in horticultural work, leaving 45 that have retired from official responsibilities, moved to other fields, or passed on to that great majority that we all must sooner or later join. As I look over the names of this group of men who have finished their work, I see

the names of five whom I knew and who influenced and encouraged me in my more youthful days. To these men I owe a debt of gratitude, which I would repay if it were possible. They do not stand out above all others, but each one had traits of character and personality that we may all recall with profit to ourselves and to those with whom we come in contact. I would not venture to risk wearying you with these personal recollections did I not know that to every one of you, similar recollections will come, perhaps of these same men, perhaps of others equally worthy of our esteem.

It is fitting to mention first, our founder, Spencer A. Beach. Modest, painstaking and conscientious in all his work, he had many qualities of mind and spirit that we may well emulate. I was once guilty of sending a questionnaire to many of the leading pomologists and the reply of Professor Beach was outstanding. It must have represented hours of thought. This was typical of the man. There was nothing spectacular or sensational about him, but everything he did was carefully and well done. Many of his contributions to horticultural science may still be considered with profit. The kind of a man he was is an example for us and our successors.

Byron D. Halsted was a charter member and continued his membership until his death in 1918. While he was not classed as a horticulturist, and did not take an active part in the Society, his work was largely with horticultural plants and his interest in our work is witnessed by his continued membership. It was my privilege to be introduced to horticultural research under his kindly direction. This was at a time when physical infirmity had compelled him to give up what had been his life work. In a new field of plant breeding he showed the same interest and enthusiasm that had characterized his work in plant pathology. He encouraged in me a faith and enthusiasm for horticultural research that I trust has continued to this day. I remember well how he would speculate on some unsolved problem of plant life and then say with a quizzical expression in his eyes, "Well, I think we will have to continue the Experiment Station another year." Dr. Halsted served his day and generation well in the field of research. More than this, he kindled the flame of human interest and kindness in every human being with whom he came in contact.

I was fortunate in coming next under the influence of John C. Whitten of the University of Missouri. His kindly and sincere interest in every human being with whom he came in contact was greater than that of any other man I have known. It can truthfully be said that he did not have an enemy in the world. He made distinct and valuable contributions to our knowledge of horticultural science, but even greater and more valuable was the influence of his character and personality on students, colleagues and friends. He was known to many of you who will join in a sincere tribute to Dr. Whitten for what he did and what he was.

Another charter member that I knew from his youth to his death was William A. Orton. Like Dr. Halsted, he was not classed as a horticulturist, but much of his work was with horticultural plants, and he continued his membership in our Society for many years. Born among



the green hills of Vermont, he grew up under the influence of their strength and beauty and spent his entire life in the service of the United States Department of Agriculture and the whole people of his country. Cut off in the midst of his usefulness by a disease then incurable, he made it a subject of scientific study and became an authority on certain phases of its treatment. His faith in the power of research for the good of mankind was unbounded. In the course of a series of lectures at Amherst he outlined a knotty plant problem. I well remember the ringing tones of his voice — "The thing can be done."

Is there one among you who knew Billy Macoun and did not admire and love him? Like many of you, I am indebted to him for many kindnesses. Cut off in the full vigor of middle life, he left results of a life work that will bless Canada for generations to come. Greater than this, he left the memory of a character and personality that is precious to all who knew him. Modest and unassuming under all circumstances, he served this Society as its president and in many other capacities. We owe him a debt of gratitude which we can discharge by striving to imitate and spread his excellent qualities of mind and spirit.

I have stressed the character and personality of these men whom I knew because they are representative of the founders of our Society and because character and personality have an importance that we rarely over-emphasize. It is now quite the fashion to dwell on these things on occasions such as this, for the world has come to expect much from research in which we bear a modest part. I remember listening to an address by a personnel officer in a well known corporation in which he showed that many more employees failed because of shortcomings of character and personality than from lack of ability. The same is true of the more or less distinct failures that I have observed among horticultural workers. Do not think that I would minimize technical knowledge and skill. A wide knowledge of the latest developments in plant physiology, chemistry and other basic sciences as well as those in the field of horticulture, is essential. But this is not enough. What we are is quite as important as what we do.

These men personify the ideals so well set forth by Doctor Bailey in his discussion before the St. Louis meeting in 1919, an address that should be thoughtfully read by every person interested in research work. They believed that truth will win its way and patiently devoted their lives to its discovery and promulgation. Their influence upon the mental attitudes of those coming in contact with them was of even greater value to mankind than the direct contributions which they made to horticultural science.

We hear much of the failures and inadequacy of science in solving the problems of mankind, yet who could calmly contemplate the loss of what science has contributed to the comforts and conveniences of life. But the greatest contribution is a saner outlook upon the world about us. Earthquakes and eclipses no longer spread terror among mankind. Fire and flood stimulate us to efforts to control and conquer. It is difficult to believe that any people will again say as was said of one of the great founders of plant science, "France has no need of scientists."

I would not suggest that even horticultural scientists are perfect. They have their shortcomings. Personally I think them the finest body of people on earth, but if some benighted individual with zoological affiliations disputes this, it is a time for discretion and not for argument.

A chemical treatment that doubles the normal chromosome number is very interesting and doubtless may prove beneficial, but the discovery of a "hormone" that would even partially inhibit the selfishness, greed, and thirst for power of human beings would be the greatest contribution that could be made to human welfare. We must confess that hundreds of years of moral and ethical training have shown meager results. The fruits of a constantly accelerating progress of research into the mysteries of nature stagger the imagination. Is it fantastic to imagine that research may some time add some such crowning achievement to the many that have already excited the wonder and admiration of mankind?

For more than 40 years I have watched the growing confidence in and appreciation of our work and services by those whom we serve. The skepticism and distrust of earlier days have largely disappeared. I sometimes say that I am careful of what I say to an audience of fruit growers because somebody may believe me. This is a heritage from our founders which we should carefully preserve and further promote. I would especially call attention to the Extension Services in the several states. Especially in recent years, these workers have rendered faithful service in tasks in which some of them have had none too much faith, yet they have performed their tasks well and I have heard little criticism of their work. If we may venture to feel that the past and present are secure, the future presents a challenge which should call forth the best that is in us.

Unfortunately for us, the total per capita consumption of food cannot be greatly increased, while there is no limit to the possible consumption of manufactured goods. We see continual changes in demand for particular foods, but an increase in consumption of one must be balanced by a decrease for some competing product. We are hearing now of proposals to utilize agricultural and horticultural surpluses to produce anticipated manufactured goods. To use a highly finished product such as horticulturists may supply, for further manufacture seems a very doubtful proposal. The raw materials for manufacture must be cheap and horticultural goods cannot be produced cheaply.

Faced with the prospects of a static population and restricted export markets, we need not further attempt the time honored objectives of making two cabbages grow where one grew before, but rather attempt to produce a better cabbage with less effort. It is a reproach to man's intelligence that in the midst of horticultural surpluses some should lack "an apple a day to keep the doctor away". May I insert parenthetically that it must require at least a half dozen apples a day to make sure of eliminating the medical man and at the same time increase the consumption of one of our principal products. Therefore we must produce apples more cheaply. Who will volunteer to invent a mechanical apple picker?

The problem of distribution is our present day ogre. It may lie in the field of the economist, the sociologist, or the politician and not in horticulture, but let us be ready to cooperate with them that all may have enough.

Is the course of democracy an autocatalytic reaction and are we approaching the end point of the reaction? If so, what can science, "pure" or applied, do to ameliorate the conditions that may prevail? These are questions that are too difficult to venture an answer. The world has been "going to the dogs" ever since history began. Yet it has never quite arrived. I wonder if the people of a thousand years ago realized that they were passing through the dark ages. Whatever may be in store for the human race, it will need more and more, a sound knowledge of the world about us and the spirit and outlook on life of the men who founded our Society. May we all consider what manner of men they were and, as may our successors in future years, strive with what powers we have to emulate them.

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